VOL. XXXI. — No. 11. NOVEMBER 1954.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

The longest electro-pneumatic braked trains in the world

To meet the peak hour needs on the Southern Region suburban lines in South-East London and North-West Kent, a number of 10-coach electric trains were brought into service on June 14th between Charing Cross and Dartford, via Bexley Heath.

These were composed by providing new two-car units of the latest Southern Region all-steel stock, which, coupled to existing eight-coach trains of similar type already running, and adding extra seating for 186 passengers, provide a total seating capacity of 958 per train.

Photograph by courtesy of British Railways, Southern Region

These new units were also equipped with

WESTINGHOUSE

ELECTRO-PNEUMATIC BRAKES

similar to those on the existing stock. These 10-coach trains are the longest now in regular service in the world fitted with this type of brake equipment.

Brakes made in England by :

Westinghouse Brakes & Signal C° Ltd, 82, York Way, London N.1


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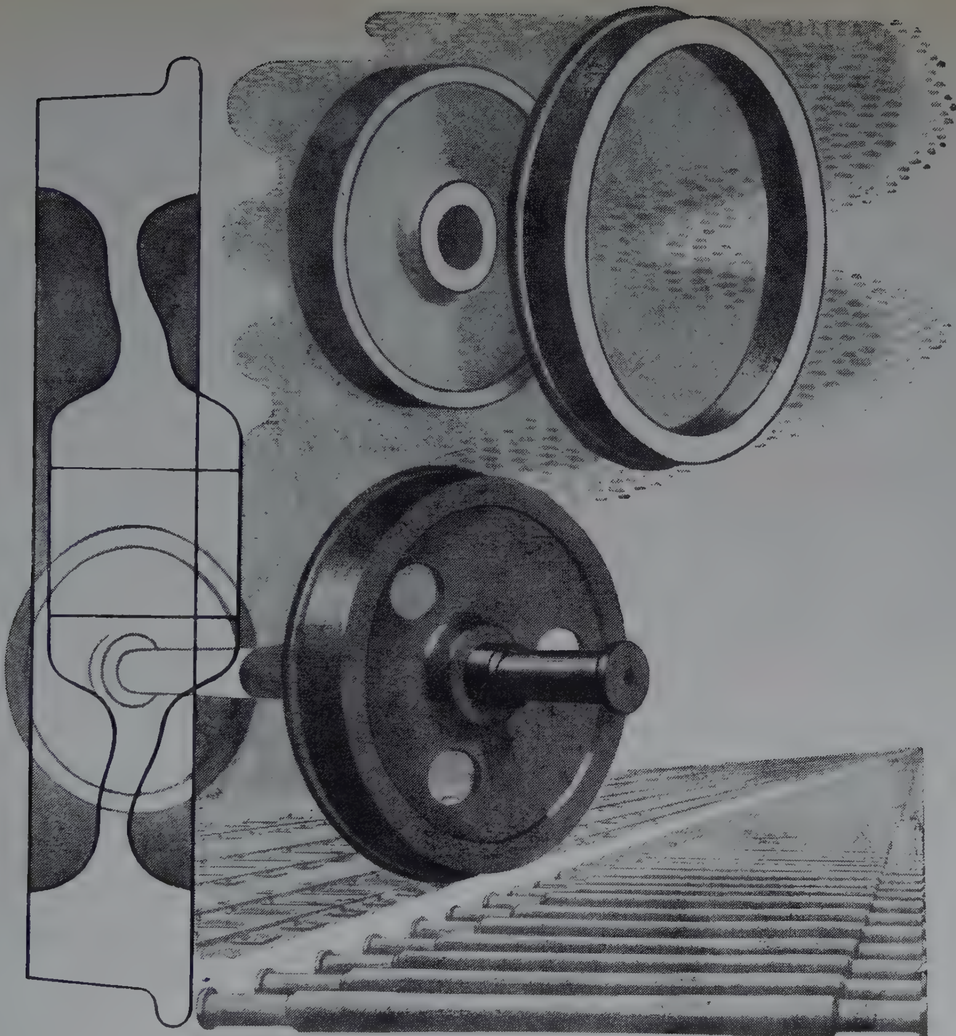

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OF THE

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(ENGLISH EDITION)

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Vol. XXXI. — No. 11. November 1954.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621 .337]

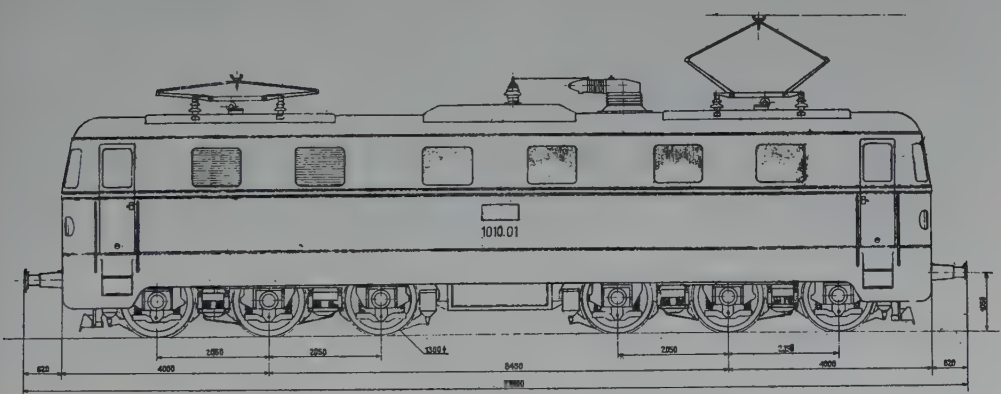
Individual axle drive.

Mechanical systems used on electric locomotives and motor coaches, with an indication of the results obtained in service on railways of all kinds,

(Continued)*

by Adolphe-M. Hug,
Consulting Engineer, Thalwil (Zurich), Switzerland.

Figure 462 is a dimensioned sketch of the eight Austrian (BBOe) mentioned above under *c)* (on the page following figure 461), which have been numbered in the series 1010.01-08 forming class 1010, still under construction in 1953. The dimensions and general arrangement are those which will probably be adopted; they relate to the position at February 1953. It will be seen that the dimensions differ from those in the figure mentioned in note (328) : the bogie wheelbase (and the wheel diameter) remain the same (as in all probability will the arrangement of the traction motors) but the distance between the inner axles of the bogies is



Plan Oesterr. Brown Boveri-Werke, EB 150.003 (November 1952).

Fig. 462. — Dimensioned sketch of 8 locomotives $C'_0C'_0$ series 1010.01 to 08, 1953, Austrian Federal Railways (BBOe) with Brown Boveri spring drive.
Note : The sketch shows the probable final form.

(*) See *International Railway Congress Bulletin*, for February 1953, p. 65 and May 1953, p. 245.

increased from 4 100 to 4 350 mm (13′ 5 7/16″ to 14′ 3 1/4″), the distance between bogie pivot centres from 8 200 to 8 450 mm (26′ 10 7/8″ to 27′ 8 11/16″) and the length over buffers from 17 000 to 17 690 mm (55′ 9 1/4″ to 58′ 3/8″).

To conclude this section on the Brown Boveri spring coupling — which is at present one of the most widely used, and so far as we know has not given rise to any difficulty — we may say that the principle is, briefly, *a spider with cross-arms* driven by dished couples located at both ends of each of the helicoidal springs encased in the gear wheel (see diagrams, figs. 146 and 190 of *Vol. II*). It will be noted that there is a similarity in principle with the SLM mechanism shown diagrammatically in figure 363; with that of figures 360 and 361 and also finally with that which will be dealt with in Chapter V. In all these cases, the drive mechanism is contained in the body of the large gear wheel (compare also the fig. 147 of *Vol. II* with the similar figure in Chapter V).

B) « *Sécheron I* » *mechanism with twin springs* (318) (301).

Whilst this coupling is comparatively old, the first applications dating from 1929/30, there are now still more applications which we shall describe below :

a) The Austrian Federal Railways (Oesterreichische Bundesbahnen BBOe) (330), already mentioned in several places, decided shortly after the second world war (in 1947) to order a further series of locomotives similar to preceding ones, with « Sécheron I » mechanism. The purpose in view was principally to reduce the delivery time and also to provide a period of comparative trials with more modern mechanisms (331).

The inevitable disadvantage of spring breakages with the « quill drive » and its derivatives was recognised; despite improved quality and manufacture of springs, there are still relatively frequent fractures. There were developed, therefore, the former series 1170, 1170.100 (fig. 94 and 95 of *Vol. I*) and 1170.200 (332), which gave series 1170.300 renumbered 1040, of which 16 locomotives were ordered (333).

Figures 463 and 464 contain a dimensioned sketch and a view in service with a train. The same « Sécheron I » coupling as series E. 45.2 (1170.200) is used. The impact limit of the springs has, however, been reduced so as to lower extreme stresses. The BBOe consider that of all

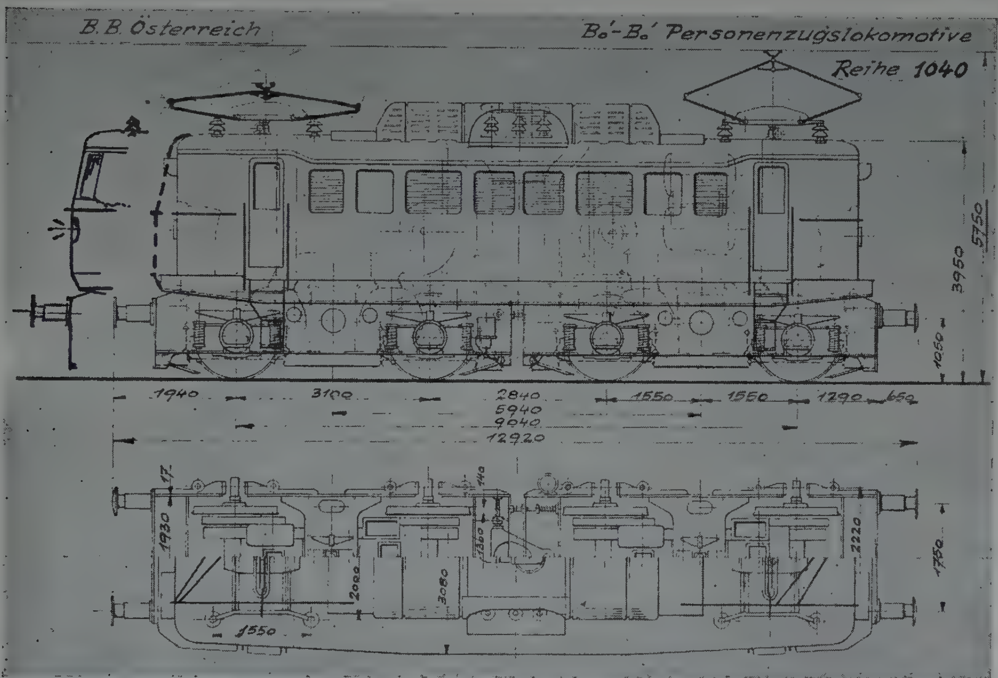
(330) The title « Oesterr. Staatseisenbahnen » shown at the bottom of the right hand column of p. 55, *Vol. II*, was only temporary; the earlier title of BBOe (Bundesbahnen Oesterreich) was restored when Austria again became (as after 1919/1920) a Confederation of States, some years after the second world war.

(331) The extension of electric traction to Vienna (Wien-Westbahnhof) created a need for a large number of new electric locomotives. Shortly after the second world war, electrification was continued on the main West-East diagonal from Attnang-Puchheim to Amstetten, where the contact line was put under load in the summer of 1951. With the last step towards Vienna, opened on the 19th December 1952, and other lines, the sections electrified increased to more than 250 km (155 miles). — See EB, Jan. 1952, p. 2, « Die Elektrisierung der Oesterreichischen Bundesbahnen », A. KOCI.

(332) These series designations became under the German occupation of Austria, from 1938 : E45, E45.100 and E.45.200, but the earlier ones were restored in 1952 when new class designations for new stock were introduced. — See table referring to BBOe series further on.

(333) See *EB*, Nov. 1952, pp. 269-275 (Fig. 1-19). « Das Elektrolokomotiv-Bauprogramm der Oesterreichischen Bundesbahnen », W. BREYER.

the types of mechanism they have in service, the « Sécheron I » is by far the simplest and requires practically no maintenance. At speeds in the region of 90 km (56 miles)/h, however, stresses in the helicoidal springs are considerable, not so much from centrifugal force as from stresses set up by excentric pulsation of the hollow shaft in relation to the axle, these forces being added to the static stress arising from the torque load. Furthermore, by reason of the rigid anchoring of the two ends of the springs, the centre line of the latter continually takes an S form. As we have already mentioned, particular care has been devoted to the manufacture of the springs and also the surface finish. Statistics do, in fact, show a reduction in the number of spring breakages, but the average rate is still one per month on the locomotives when they have been in service about a year. It has therefore been decided that for express passenger locomotives (maximum speed: 120 km [74 miles]/h) the « Sécheron I » mechanism is no longer to be considered, and for new series the AEG mechanism « Federtopfantrieb »



Plan BBOe, completed on the left.

Fig. 463. — Dimensioned sketch of 16 $B'_0B'_0$ locomotives of the BBOe class 1040. The first ten, Nos. 1040.01 to 10 have vertical end walls; the next six, Nos. 1040.11 to 16 have rather longer bogies with shaped ends, as shown on the left.

will be used; this will be dealt with under *C)* below. Supply difficulties in connection with raw materials have in the event not allowed the desired reduction in delivery period, so that the new developments are also to continue forthwith.

Photo W. Wagner No. 846.

Fig. 464. — Locomotive No. 1040.07 in service with a train on the southern gradient of the Tanern running towards Villach. The locomotive is still carrying the old class designation No. 1170.307.

Various improvements have therefore been incorporated in the new class 1040 locomotives of the series E.45.2 (1170.200); figs. 3 to 5 of the publication mentioned in note (333) show some interesting features of the bogies and their connections which are new; fig. 6 shows the new type of Friedmann forced lubrication axlebox and fig. 16 (again from the BREYER article) shows a traction motor.

These 16 locomotives carry the numbers 1040.01 to 1040.16. They are built by the « Wiener Lokomotivfabriks » Lofag (or WLF) for the mechanical parts and by the ELIN Co. (Sécheron agents) for the electrical equipment and assembly, that is the same organisation as previously (see *Vol. I*, p. 44). As in the earlier case, the body has a three

point bearing on each bogie with adjustable return springs. In figure 463 can be seen the two types of body ends: the first ten locomotives, Nos. 1040.01 to 1040.10, ordered in 1950, and put into service during 1952, have a shorter body and vertical end walls, whilst 1040.11 to 1040.16, ordered in 1952 and still under construction at the beginning of 1953 have a longer body and the upper part of the end walls is profiled. This is shown on the left of figure 463.

To show clearly (in view of the various changes in numbering of the series) the machines still in service fitted with the « Sécheron I » coupling, *all* $B'_0B'_0$ *type*, and bilateral drive, we give the following table: (see next page).

The principal characteristics of the new series 1040 locomotive, not already given, are as follows:

Hourly power: 3 220 H.P. at a speed of 64 km (39 miles)/h;

Max. starting tractive effort: 20 tons;

Tare : 81 tons (79.5 tons for the Nos. 01-10, with shorter bodies);

Load per driving axle : 20.25 t (19.9 tons);

Gear ratio: 21:93 (spur gears);

Gearing and coupling : bilateral.

This comprises everything that can be stated about the B_0B_0 locomotives with « Sécheron I » couplings of the Austrian Federal Railways (BBOe).

b) We have already mentioned an application of the same « Sécheron I » mechanism to a bogie (two driving axles) of one of the motor brake vans, class Fe 4/4 of the *Swiss* Federal Railways (CFF) (fig. 444). This application (conversion of the bogie) was carried out in 1933 on motor coach No. 18524 (re-numbered 824) and the bogie in question is the leading one (with Isothermos boxes) which is shown in figure 160 [corresponding legend is that of figure 42, see note (334)]. This bogie is still in service and is the second bogie of the converted motor coach No. 824, the same one as mentioned above. Dealing with the Oerlikon rubber coupling (which we have designated Oerlikon VI), it was noted at the bottom of the page with figure 444 that the other bogie, and also the six on cars 821 to 823, have the new Oerlikon rubber pad coupling (fig. 442).

There are some 40 locomotives and motor coaches still in service on various systems in Switzerland with the « Sécheron I » mechanism, totalling about 200 driving axles.

c) With regard to *Russia*, we have already mentioned (335) the application of the « Sécheron I » mechanism to two diesel-electric locomotives, prototype ML. 6 (?) class, i.e. the 1 Eo 1 type of 1930 (1 200 H.P. hourly rating, weight in running order = 135 t) and the 2 Eo 1 type of 1931 (1 650 HP hourly rating, weight in running order 149 tons. Gauge: 1 524 mm (5′ 11/16″). These two locomotives had an adhesive weight of 105 tons or

(334) See top of p. 44, *Vol. II* (December 1947, *Congress Bulletin*, p. 1006, see fig. 42) and sub-title of fig. 42 and 160 which were reversed in error. See Erratum 44, p. 312, *Vol. II.*

(335) See *Vol. II*, pp. 47-50 *(Congress Bulletin*, December 1947) fig. 47-50.

Austrian locomotives (BBOe) B'$_0$B

Item	Original number of locomotives	Year put into service	BBOe series designation up to 1938 or since 1952	German designation 1938-1945 maintained until 1952	Probable designation from 1953	Number in service at the end of 1952	Maxi spe in se kn
1	14	1927/28	1170	E 45	1045	01-10	6
2						11-14	6
3	15	1929/31	1170.100	E 45.100	1145	101-106	6
4						107-115	6
5	8	1934/36	1170.200	E 45.200	1245	201-208	8
6	43	1936/40	1170.200	E 45.200	1245.500	209-241	8
7	10	1950/51	1170.300	—	1040	01-10	9
8	6	1953	—	—	1040	11-16	9

96 locomotives in all

Siegl = Siegl Locomotive Works, Vienna Neustadt.
Lofag (or WLF) = Wiener Lokomotivfabriks SA., at Vienna Floridsdorf.
ABES = Association of four Austrian electric equipment manufacturers : AEG/BBC (Brown Boveri)/ELIN/SSW (Siemens-Schuckert).

21 tons per driving axles. It is not known if other locomotives of this type have been built in Russia but it is known that operating conditions on the Soviet Railways (to which we shall return later in regard to the AEG mechanism) are not very favourable for internal combustion engines, partly because of the great seasonal variations in temperature (sometimes below — 40° C in winter), partly because of the tropical type of rainfall in some regions, and partly because of the extremely bad dust, which cannot be filtered. These conditions, however, impose the same difficulties for steam traction (even for condensing locomotives), particularly in view of the low water supply in certain areas. From a technical aspect of locomotive maintenance, electric traction is much more favourable.

Among other applications in *Switzerland*, the following may be mentioned:

d) In 1950, the two 1 C_0-C_0 1 locomotives of the Swiss Bernese Alps Railway (BLS) Nos. 207 and 208 (class Ae 6/8) were fitted with « Sécheron I » mechanism. These are the two locomotives already described (336) (figs. 127 and 128, *Vol. II*) which were first fitted with the

(336) See p. 104, *Vol. II (Congress Bulletin*, April 1948, p. 244).

. $B_0 + B_0$) with « Sécheron I » mechanism.

eel a. m	Makers: mechanical parts	Makers: electrical equipment	Number destroyed during the war Nos.	Number of locomotives remaining in 1952/53	Figures Nos.	Gear ratios	Type of gear (bilateral)
00	Siegl	ELIN	02 and 05	8	94 (*Vol.I*)	1 : 5.867	Maag, oblique
00	Lofag	ELIN	—	4			
00	Krauss, Linz	ELIN	101 and 103	4	95 (*Vol.I*)	1 : 5.867(*)	»
00	Lofag	ELIN	—	9			
50	Lofag	ABES	206	7	see pp.55 and 57 (*Vol.II*)	1 : 4.43	Maag, spur.
50	Lofag	ABES	215	42	—	1 : 4.43	»
50	Lofag	ELIN	—	10	462	1 : 4.43	»
50	Lofag	ELIN	—	6	462-463	1 : 4.43	»

Locomotive No. 104 at first had a gear ratio of 1 : 4.42 for experiments at 85 km (53 miles)/h but was later verted to a ratio of 1 : 5.867 like the remainder.

Sécheron piston type mechanism, which as we know, has not given satisfactory results and is no longer being fitted.

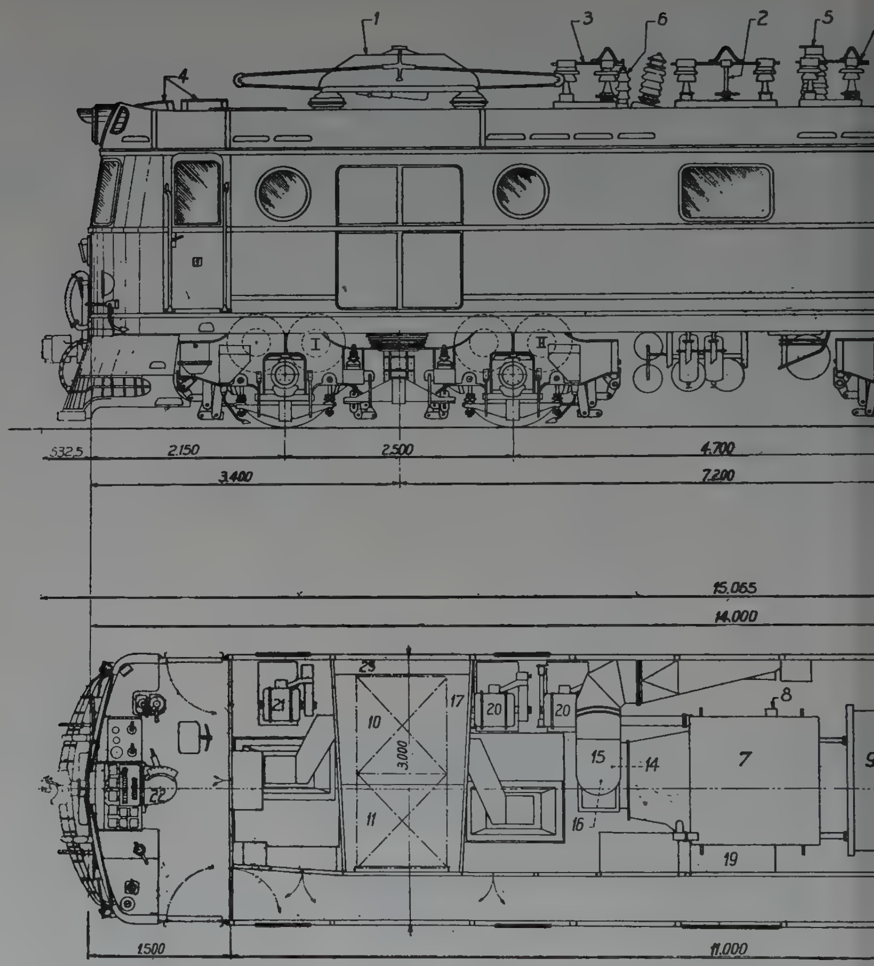
e) In 1952, BCFe 2/4 class motor-coach No. 44 of the Bodensee-Toggenburg BT (N. E. Switzerland, St. Gall) was fitted with « Sécheron I » mechanism (on the two axles of the driving bogie only, the other being a carrier). Diameter of driving wheels: 1 040 mm (3′ 4 15/16″); maximum speed: 90 km (56 miles)/h (compare figs. 38 and 39 of *Vol. II*).

f) In 1946, the Emmental-Burgdorf-Thun Railways (EBT) also in *Switzerland*, and already mentioned (337) ordered a Be 4/4 class locomotive, No. 109, and in 1953 another one, No. 110. Wheel diameter: 1 060 mm (3′ 5 6/8″); maximum speed: 75 km (47 miles)/h.

g) In 1951/52, the *Belgian Congo* ordered from the Ateliers de Constructions Electriques de Charleroi ACEC, already mentioned several times in connection with the same drive mechanism (338), twelve electric locomotives of the $B'_0B'_0$ type, Nos. 1 to 12, for the

(337) See pp. 41-43, *Vol. II*, fig. 37 *(Congress Bulletin*, December 1947, p. 1003) and *Vol. I*, fig. 99, p. 45, regarding similar locomotives of the BT Railway (and SMB) mentioned under *e*) above (and page following fig. 461).

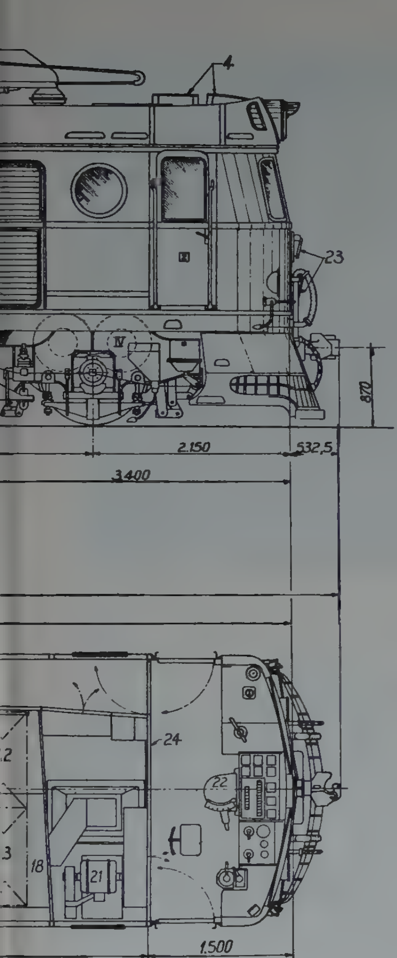
(338) See figs. 54-63 of *Vol. II (Congress Bulletin*, December 1947).



BCK (Bas Congo-Katanga) (339). These locomotives are destined for the 105 km (65 miles) long line from Jadotville to Tenke (later to be extended to Kolwezi, twice the distance) a section of the line from Elisabethville, North-westwards towards the frontier of Rhodesia, which was electrified in 1951, with high tension single phase industrial frequency current (25 kV, 50 cycles). Gauge 1 067 mm (3′ 6″).

Figure 465 is a dimensioned sketch of these locomotives, and figure 466 the first locomotive of the series completed

(339) See *Congress Bulletin* ET, April 1953 pp. 49-89, II : « Description of the single phase 25 kV, 50 cycle locomotives built by the « Ateliers de Constructions Electriques de Charleroi »; in the article p. 49 « The Electrification of the Jadotville-Tenke section of the Railway operated by the B.C.K. Company (Compagnie du Chemin de fer du Bas-Congo au Katanga) in the Belgian Congo. »



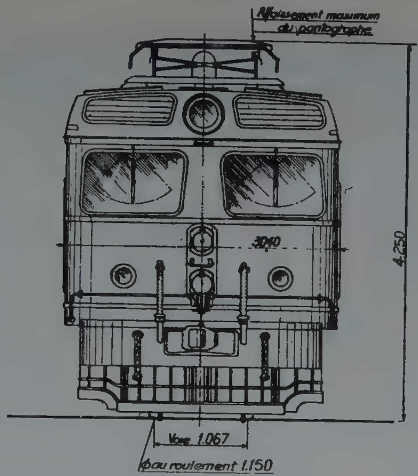


Fig. 465. — Elevation, front view and horizontal section through the body of the 12 $B'_0B'_0$ electric locomotives, Nos. 1 to 12 of the Bas Congo-Katanga (BCK) Railway, Belgian Congo, with « Sécheron I » drive mechanism (see figs. 466 and 467).

Note. — For description of component parts (figures) see publication in note ([339]), fig. 15.

Builders :

Mechanical parts : « SA. Les Ateliers Métallurgiques », Nivelles;

Electrical parts : « Ateliers de Constructions Electriques de Charleroi, SA ».

Plan Ateliers Métallurgiques Nivelles and A.C.E.C.

and figure 467 the group of two twin motors of one axle with the gear case and the terminal points for the springs to the hollow shaft.

These BCK locomotives give an hourly power at the tread of about 1 500 HP for a speed of 47.5 km (29 miles)/h. The maximum speed in service is 70 km (43 miles)/h. Wheel diameter (new): 1 150 mm (3′ 9 9/32″). Gear reduction ratio: 1 : 6.93.

C) *Couplings with pairs of springs. « Quill cup drive » and « Federtopfantrieb »* ([319]) ([300]).

As we have just dealt under B) above with the new Austrian locomotives with « Sécheron I » mechanism, we will commence under this heading with the twenty-five new locomotives of the same railway, fitted with the « Federtopfantrieb » transmission. These are the class 1041, $B'_0+B'_0$ type — the bogies are linked together —

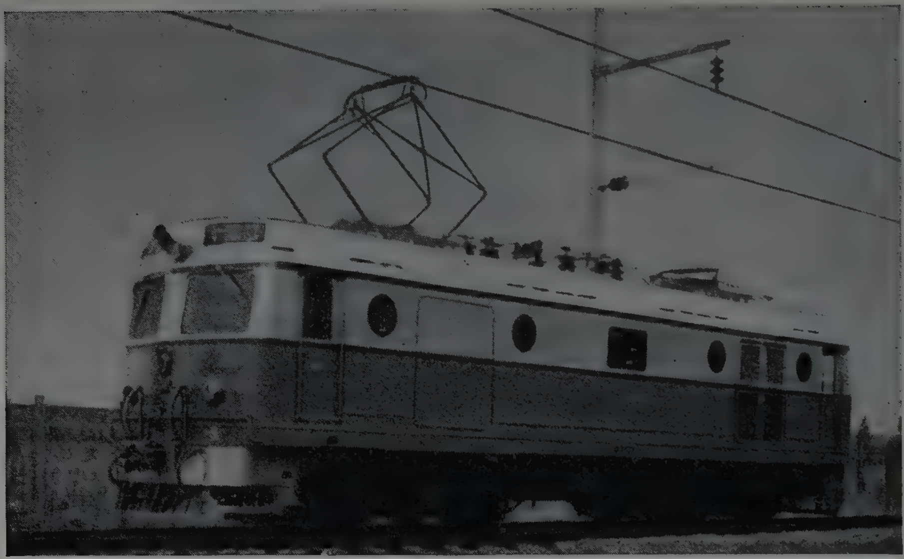


Fig. 466. — View of the first locomotive of the series in fig. 465.

Nos. 1041.01 to 1041.25 [see notes (331) and (333)], figure 469 containing a sketch of the first 15 (Nos. 1041.01 to 1041.15) which were ordered in 1951 under class No. 1170.400 and have since been given their new class designation (1041). The following ten machines of this series (1041.16 to 1041.25) have ends of snow-plough form (340).

Figure 469 shows one of these locomotives hauling an express train. These 25 locomotives have therefore the AEG coupling (also known as Kleinow) with socketed springs (European type). Comparing figures 463 and 468, it will be seen that the two series have many similarities, but the series 1041 are in particular longer, and have a larger wheelbase. They consequently weigh

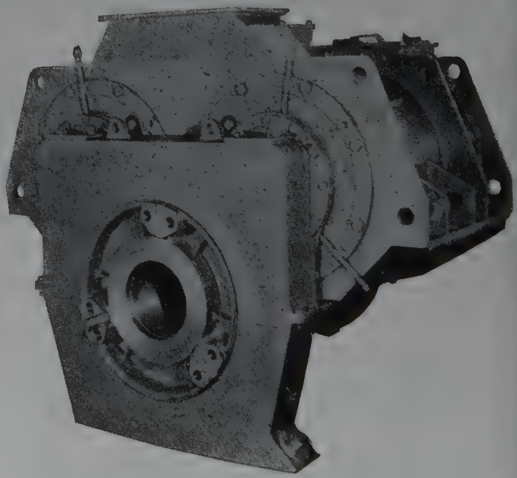
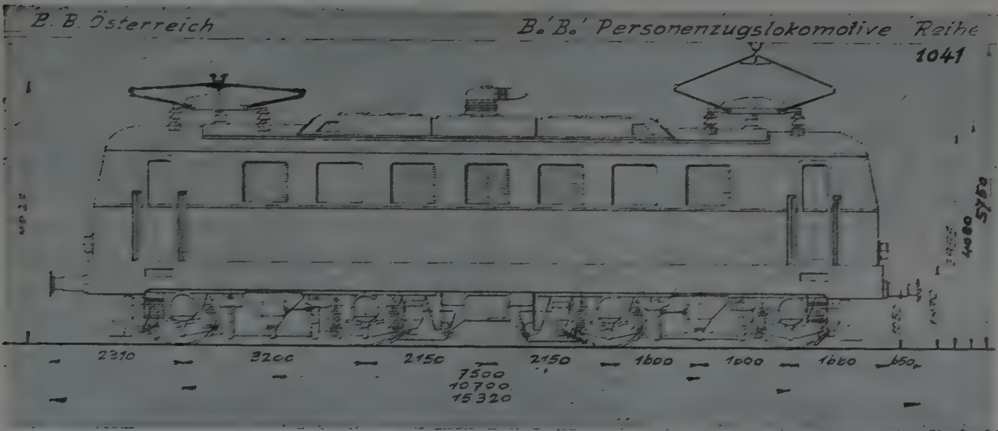


Photo ACEC.

Fig. 467. — Motor group of one axle of locomotives in figs. 465 and 466, showing the twin motors with gear case and end of hollow shaft, to which are fixed the driving springs (cf. figs 81, 88 and 96, *Vol. I* and 50-52, *Vol. II*).

(340) See the publication in note (333), continuation in EB, December 1952, pp. 301-303, particularly with regard to the suspension and linkage of bogie frames, figs. 22 and 23 (p. 302).



Plan BBOe.

Fig. 468. — Dimensioned sketch of 25 locomotives, series 1041.01 to 25 of the Austrian Federal Railways (BBOe), with Kleinow-AEG mechanism cupped spring drive.

Fig. 469. — Locomotive No. 1041.03 of the BBOe with express train passing through a station. On the leading, lowered, pantograph can be seen the special SSW bow, mentioned under 2) in the text.

Photo SSW.

4 tons more and have an axle load of 21 tons.

The two new classes 1040 and 1041 are fitted with the same motors (41 locomotives) and thus have the same characteristics and speeds, the wheel diameters also being 1 350 mm (4′ 5 1/8″) [340].

Locomotives 1041.01 to 1041.15 were equipped electrically by the three firms (5 each) AEG (01, 04, 07, 10, 13), BBC (02, 05, 08, 11, 14) and SSW (03, 06, 09, 12 and 15); of the following ten Nos. 1041.16 to 1041.25, six were equipped by ELIN, one by SSW, one by AEG and two by BBC. The mechanical parts for the complete series of 25 locomotives are from the Graz Works of the Simmering-Graz-Pauker Company.

We can now proceed to the BBOe (Austrian) 1-D_0-1 locomotives with AEG-Kleinow coupling, to complete, so far as Chapter IV is concerned, the Austrian spring-coupled locomotives.

We have already mentioned [341] the 8 class 1870 locomotives, ordered in 1937 and put into service successively up to 1942. A dimensioned sketch is included in figure 86 of *Vol. II*. These 8 locomotives, Nos. 01 to 08, were designated during the German occupation as class E. 18.200 and in 1951 redesignated 1018. The locomotives were built by the Vienna-Florisdorf Works already mentioned (Lofag-WLF); the electrical equipment for the first four was provided by the AEG and for the second four by SSW.

Figure 470 shows two of these locomotives hauling an inaugural train. We may also note that locomotive 1870.06 was partially destroyed during the war; in reconstruction it has been made into a single locomotive (also 1 D_0 1, with socketed spring transmission) numbered 1018.100 which was returned to service in 1952.

Fig. 470. — Inaugural train for electrification of Amstetten-Vienna line, hauled by two 1'$D_0$1 locomotives, class 1018, BBOe, built by Siemens-Austria.

Before passing to locomotives of other railways with the same mechanism, we may mention in connection with these Austrian locomotives, three special features, two of which concern the collection

(341) See *Vol. II*, p. 72 (*Congress Bulletin*, February 1948, p. 86).

of current by the pantographs and consequently do not properly come within the scope of this article (although efficient collection of current from the contact wire is partly dependent on the smooth running of the locomotives); the third of these features concerns the coupling arrangement of the two bogies.

1) *Lowering of one of the pantographs.* The various dimensioned sketches of the Austrian locomotives (figs. 462, 463 and 468) show one pantograph raised and one pantograph lowered. The BBOe have in fact an automatic device which lowers the leading pantograph as soon as the driver takes up his position; the trailing pantograph only is operative (figs. 464 and 469).

2) *Special type pantograph bow.* This new arrangement called « Type IV » can be seen on the leading (lowered) pantograph of figure 469. This device which has to provide for running with a single pantograph under all types of operating conditions consists of a double bow with bascule suspension by two lever arms about a tube located between the two rubbing bars, which have about 30 cm (11 13/16″) spacing. The weight of this bow friction bar is as low as possible; the device gives a life of the carbon rubbing blocks up to 70 000 km (43 500 miles). Trials with the aim of improving the rubbing bar fixing are not yet completed [342].

3) *Coupling between the two bogies of a locomotive.* — We have mentioned that the Austrian locomotives classes 1040 and 1041 have a mechanical link between the bogies. These are shown in figures 3, 4 and 5 of the publication referred to in note [333], and figure 23 of note [340]. It is considered difficult to state definitely whether the two bogies should be linked and if the connection should cater for tractive effort or if it should only provide a side control. All this depends on the type of locomotive, loads and wheelbases, track conditions and special operating requirements. Generally, a decision can only be made after practical tests; it is intended to deal further with this in Chapter VI, in connection with the S.N.C.F. locomotives Nos. 9001 and 9002.

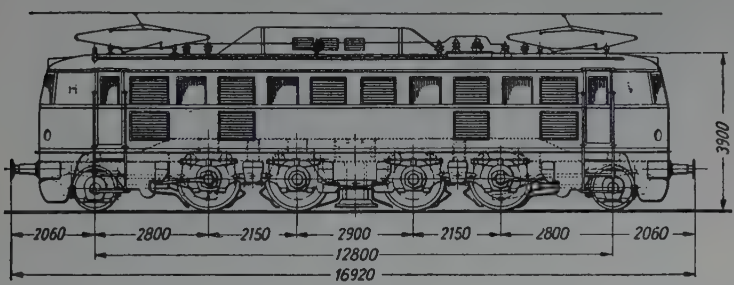


Fig. 471.— Dimensioned sketch of German DR (now DB) locomotives, class E.19, for max. speed in service of 180 km (112 miles)/h (cf. fig. 80, *Vol. II*).

From Henschel.

With regard to the *German* 1 D_0 1 locomotives, with cupped spring transmission,

[342] See publication mentioned in note [333], figs. 9, 10 and 11, also *Siemens Technische Berichte*, Vienna, No. 1, March 1952 : « Die Entwicklung der Stromabnehmer für die Oesterreichischen Bundesbahnen » (15 figures and diagrams) E. PAWELKA.

these have also been mentioned ([343]) and reference may be made to Table C (*Vol. II*, p. 69) and to figures 80, 81 and 83. These are the E. 18 series (maximum speed in service: 140 km [87 miles]/h) and E. 19 (maximum speed in service: 180 km [112 miles]/h) of the « Deutsche Reichsbahn » now (for Western Germany) the Deutsche Bundesbahn DB. Figure 471 includes a dimensioned sketch of the E. 19 class.

We now pass to applications in *Russia* of cupped spring transmission, previously mentioned ([344]) and it will be recalled that the Soviet Railways have a track gauge of 1 524 mm and in 1952 had 120 000 km (74 564 miles) of track, being therefore generally of a low density when considered in relation to the territory served.

It may be mentioned in passing that there are in the U.S.S.R. six different systems of current for electric traction (which it is as well to bear in mind) as follows:

1) 1 200 V, D.C., since 1924 (experimental electrification of the Bakou to Sabuntchi line in the Transcaucasus on the Caspian Sea);
2) 550-750 V, D.C., since 1932 (industrial and mining lines in the Urals and in Siberia);
3) 3 000 V, D.C., since 1932, almost all main lines electrified, in particular the Transcaucasian (Suram pass, gradients up to 33 $^0/_{00}$) mining regions of the Krivoj-Rog, Donbass; Urals; Sverdlovsk, etc., Murmansk line (on the Berents Sea, in the Arctic circle); the Transiberian between Chelyabinsk and Zlatooust, 200 km (124 miles), 1945, etc.;
4) 1 500 V, D.C., since 1935 (short experimental line, Mineralnie-Voldi-Kislovodsk and Zheleznovodsk on the northern flank of the Caucasus (branch of the 1 300 km [807 miles] line from Rostov, N.E. of the Sea of Azov to Baku) having gradients of 36 $^0/_{00}$), in addition to the metropolitan and suburban lines in Leningrad, Moscow, Tallinn (Estonia) and Karkow ([346]).
5) 15 kV, 16 2/3 cycles, single phase, since 1948 (?) line in the South and mining regions of the Petchora (Arctic regions) ([347]).
6) 20 kV, 50 cycles, single phase (experimental lines of a total of about 100 km [62 miles]) since 1952 (?), Mara-Torbino lines (?) and Lichoslav section of the Kalinin-Bologoje line (?).

Practically all the Soviet electric locomotives are of the $C'_0C'_0$ or $C_0 + C_0$ type with nose-suspended motors, bilateral transmission with gears having a flexible rim on 22 springs of 8 laminations. It

([343]) See *Vol. II*, pp. 68-72 *(Congress Bulletin*, February 1948). Also notes ([57]) and ([58]), p. 69.

([344]) See *Vol. II*, pp. 66-68 *(Congress Bulletin*, February 1948) and column 10 of Table A, p. 63.

([345]) See *Le Génie Civil*, Paris, No. 3298, 1st April 1951, pp. 124-129, « La traction électrique en U.R.S.S. », 4 maps, 3 figures, table, Y. MACHEFERT-TASSIN. — See also EB ,No .2, 1952, pp. 37-43, « Elektrische-Zugförderung in Russland », 9 fig. and diagrams, 4 tables, W. HÜRLIMANN.

([346]) It was intended later to convert the lines at 1500 V to double the tension at 3000 V, to standardise the voltages and to save copper.

([347]) The equipment for this line was obtained partly from the de-electrified zone of Leipzig-Magdeburg and Saalfeld-Halle in the Russian occupied zone of Germany.

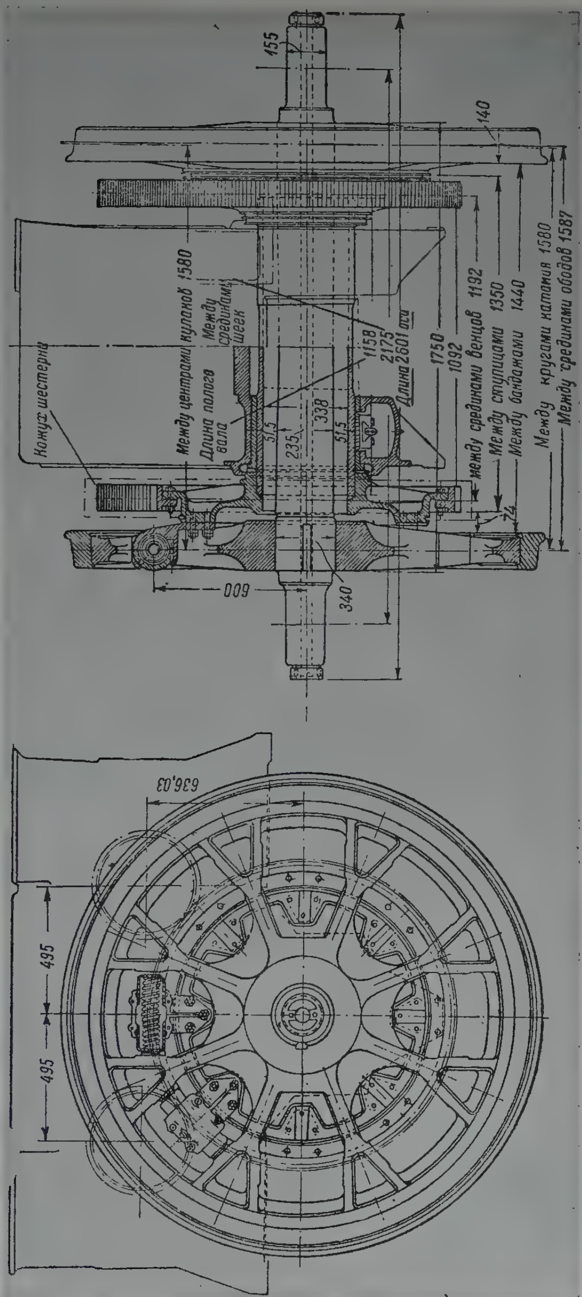


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Fig. 472. — Axle equipped with twin motor, elevation and vertical section through the axle centre, for 2-C_0-2 type locomotives, BP 21 class of Soviet Railways. Cupped spring mechanism, AEG-Kleinow type, with hollow shaft carried by the twin motor arms. It will be seen that the gears (spur) and mechanism are bilateral (Cf. fig. 102-104 of *Vol. I.*) Dia. of driving wheels 1850 mm.

appears that all the locomotives built in Russia have the same standardised motor, or very similar ones (at 3 kV, D.C.). These are for the C_0C_0 type (see fig. 78, *Vol. II*) of the SS series (or S-s Sourmanski-Sovietski, 1931), SI (or S-i built in Italy since 1931), VL 19 and 21 (Vladimir Lenin 1932) SK 22 (Serge Kirow, 2 series, from 1935), VL 22 (1946) and SK 23 (1947) (348).

The locomotives of the 2 C_0 2 type for express trains appear to have cupped spring mechanism; these are the PB 21 (Polit Buro) and two series, of which one has the AEG coupling (German licence) (349); the other, probably having the Westinghouse « quill cup drive » (American licence). Transmission and gears are bilateral this being facilitated by the wide gauge. The locomotives were built by the « Dynamo » and « Kolomna » Works. The maximum speeds in service for these two series are 115 and 130 km (71 and 81 miles)/h; they weigh 121 and 131 tons respectively with 65 tons adhesive weight, the maximum axle load varying between 21.7 and 22.5 tons. All these locomotives have twin motors to each axle, in accordance with figure 472; the arrangement is somewhat similar to that in figures 81 and 102-103 of *Vol. I* and 50 and 105 of *Vol. II*. The hourly rating of these locomotives is 2 760 HP (920 per axle), with 11 tons corresponding tractive effort. The diameter of the driving wheels is 1 850 mm (6′ 7/8″) (new) whilst that of the other series (C_0C_0, 1 C_0C_0 1, 2 D_0D_0 2 and B_0B_0 + B_0B_0) (350) is in all cases between 1 120 and 1 220 mm (3′ 8 1/32″ and 3′ 11 1/16″).

To conclude the Russian locomotives, we show in figures 473 and 474 dimensioned sketches of two of the principal classes, VL 22 and SK 22 and 23, C_0C_0 locomotives, 3 000 V D.C., standard type nose-suspended motors. We may note on this subject that the SS class locomotives (fig. 475) and VL class (fig. 473) mentioned above have an unusual and very interesting link between the body and the bogies; whilst one of the bogies turns normally on a pivot (diameter of socket: 450 mm = 1′ 5 11/16″), the other is displaced in relation to the body *longitudinally only*, without rotation, by 37.5 mm (1′ 2 41/64″) in each direction. This arrangement permits the taking of 145 m (153 yards) radius curves at speed [see note (345) and figure 475, plan of middle axle].

(348) The figures following the class designation letters show the axle load, in tons. — Locomotives of class VL. 19 will have the original Westinghouse drive, in accordance with fig. 72 of *Vol. I*.

(349) See EB, June 1936, pp. 156-157 « Die erste elektrische Schnellzuglokomotive PB 21 der Sowjetunion ».

(350) There are only two prototype $1C_0C_01$ locomotives (1937) of 3 500 HP hourly rating corresponding to a tractive effort of 27 tons, load per driving axle : 23 tons.

Of the $2D_0D_02$ type series, 15 locomotives were built in the U.S.A. in 1949, but their delivery was not authorised. They were converted for standard gauge of 1 435 mm (4′ 8 1/2″) in 1950; 12 have since been working on the Chicago-Milwaukee-St. Paul and Pacific Railroad, 3 000 V D.C. (mentioned several times in *Vol. I and II*.) and 3 others on the South Shore Railroad (1 500 V D.C.) with motors in parallel. They have 23 tons load per driving axle, hourly rating of 5 530 HP with a corresponding tractive effort of 35 tons; dia. of driving wheels 1 120 mm (3′ 8 1/8″) maximum speed in service 110 and 130 km (68 and 81 miles) /h.

Finally of the B_0B_0 + B_0B_0 (1951) locomotives, some are diesel-electrics and there is a prototype single phase 20 kV, 50 cycle with rectifier.

We will describe later, at the end of this Chapter, a quill cup drive mechanism encased in the gear wheel (an application in Great Britain) and proceed now to the Pennsylvania type « rubber drive » described in several places in *Vol. II* (figs. 117, 323-325, etc.).

b) by the TGOJ Railway (Trafikaktiebolaget Grängesberg-Oxelösunds Järnvägar), Eskilstuna, a number of $C'_0C'_0$ and $B'_0B'_0$ type locomotives (same axles and motors in each case) weighing 105 tons and 72 tons respectively; all equipped for working as multiple units. The $B'_0B'_0$ have low tension control, but the $C'_0C'_0$ have high tension. The latter have an hourly rating of 4 500 HP, maximum speed 105 km (65 miles) h.

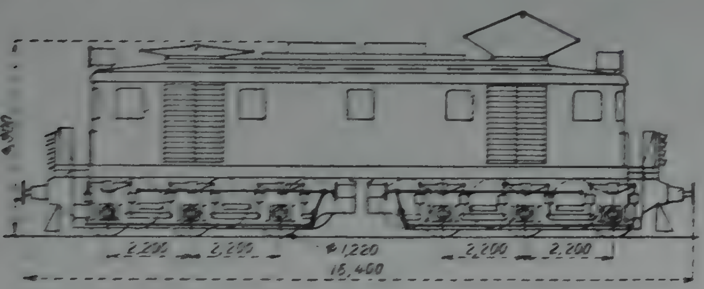


Fig. 473. — Dimensioned sketch of Soviet locomotives $C'_0C'_0$ type, class VL 22.

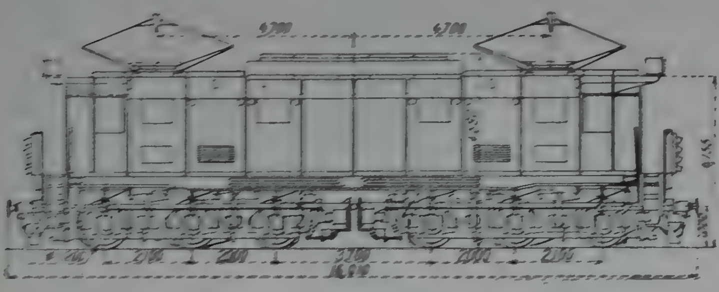


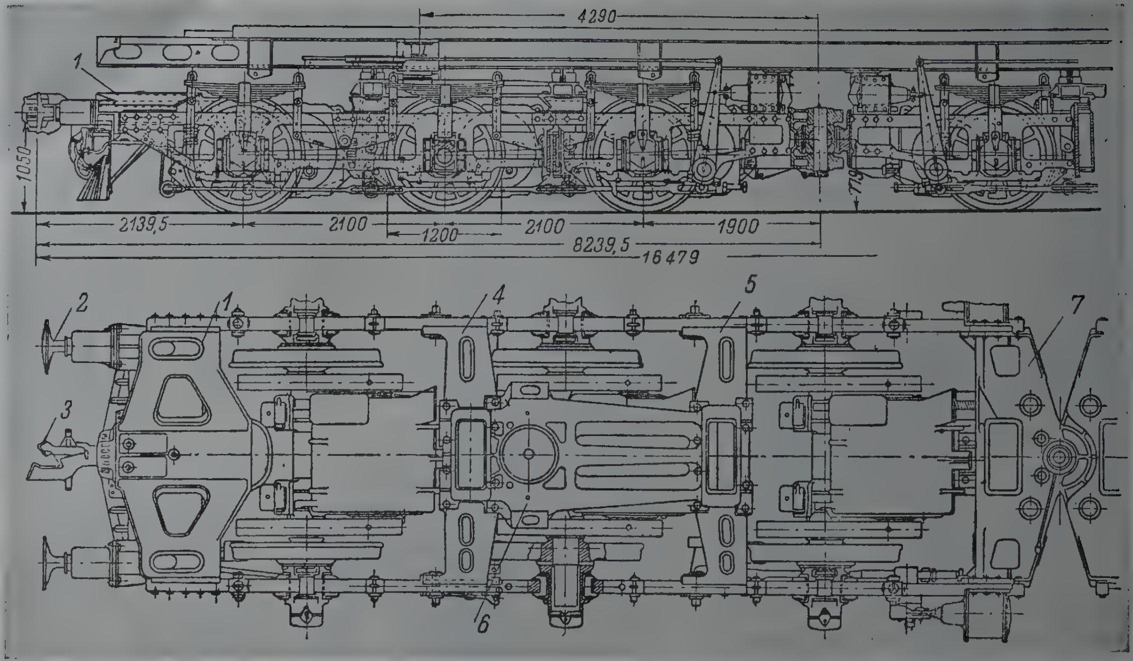
Fig. 474. — Dimensioned sketch of Soviet locomotives C_0-C_0, classes SK 22 and 23.

A certain number of locomotives were ordered in 1952 *in Sweden* with this transmission, as under:

a) by the Swedish State Railways, SJ, a number of $C'_0C'_0$ locomotives, similar in their general arrangement to the previous ones, but more powerful (4 500 HP hourly rating), faster (maximum speed in service: 100 km [62 miles] h) and with a maximum axle load of 18 tons. These locomotives will work freight trains in Southern Sweden and express trains in the Northern regions.

Returning to the ALBEN-SW coupling (fig. 450), we have mentioned another application, somewhat different, on the $B_0B_0B_0$ locomotive No 6002 (fig. 454) of the French National Railways S.N.C.F. (351). Figure 476 shows this coupling as it is to be fitted in 1953 to six axles of this locomotive, which may be described as follows.

(351) See page with fig. 452 and top of following page (*Congress Bulletin*, May 1953, pp. 267-268).



Block « Elektrische Bahnen ».

Fig. 475. — Elevation and plan of the bogie for the Soviet C_0+C_0 locomotives SS class, for freight services. In the plan view (on a larger scale) as well as in the elevation, the coupling between the two bogies and the automatic drawgear.

1. outer cross member of the bogie frame, allowing longitudinal sliding movement (see text).
2. buffers (1524 mm gauge).
3. automatic drawgear.
4. and 5. middle-beam of bogie frame, allowing longitudinal displacement of pivot 6.
6. bogie pivot.
7. inner cross member of bogie frame, carrying the pivoting link between the two bogies.

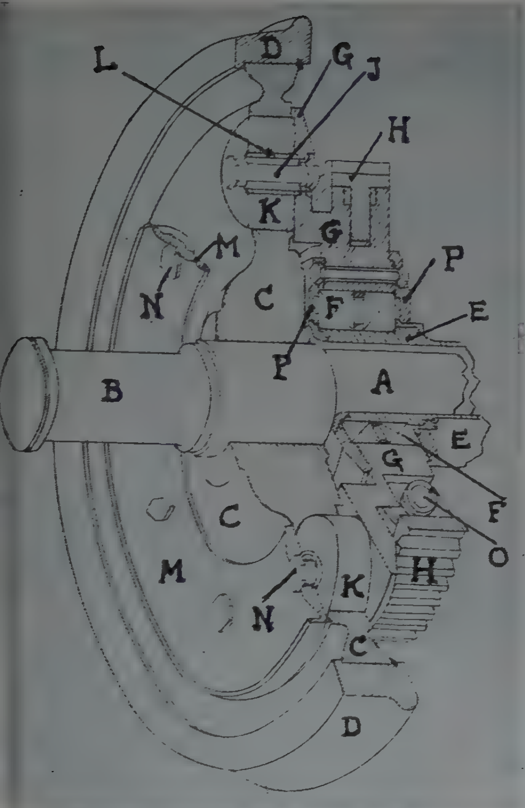


Fig. 476. — Diagram of Alben-SWII mechanism for SNCF locomotive, No. 6002, $B_0B_0B_0$, type of fig. 454 (cf. figs. 450, 452 and 453).

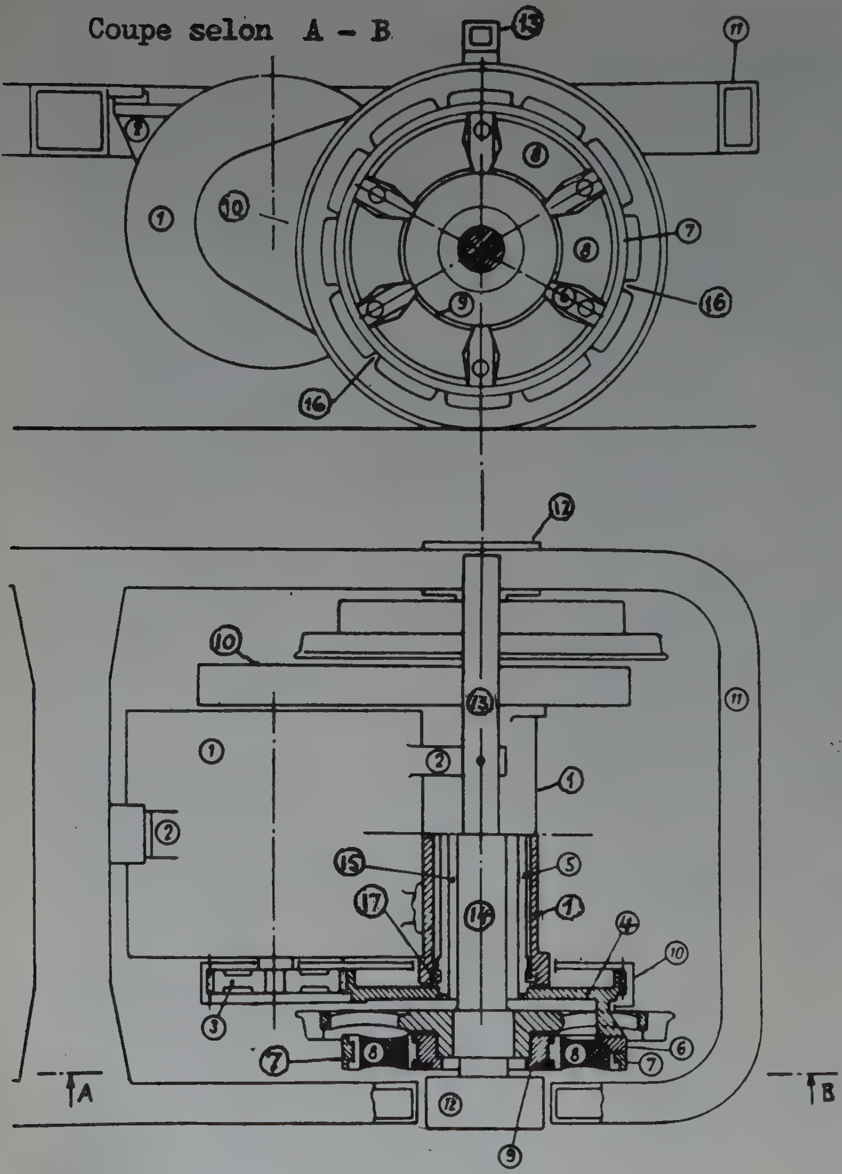
A = axle.
B = journal.
C = wheel centre.
D = tyre.
E = hollow shaft forming part of the traction motor body.
F = roller bearing to allow rotation of gear wheel G on E.
G = gear wheel body with disc for driving pins J.
H = flexible geared rim (fig. 452-453).
J = driving pins with rubber pads K in the body of the wheel.
K = rubber pads.
L = tubular facing of pads K.
M = retaining and locking ring for rubber pads K in the wheel centre C.
N = fixing bolts, for ring M and plate G of gear wheel centre on driving pins J.
O = springs of flexible gear wheel.
P = sealing and retaining covers for bearings F.

In place of a hollow shaft rotating in bearings located in the carriers (on the axle) of the traction motor body (as shown in fig. 450), the hollow shaft itself does not turn but is held in the two carrying arms of the motor and thus forms a part of the motor body. On each end of the hollow shaft are two roller bearings on which the body of the gear wheel, in which the bearings are set, rotates. It is this gear wheel body — which has a flexible rim, as in figure 452 — which carries the arms bearing the driving pins, round which are the rubber cushions, set in the body of the wheel (as in fig. 450).

The gears and the rubber mounted drive mechanism are bilateral. We will call this alternative arrangement the ALBEN-SW II.

We have dealt at the end of Chapter III [and in note (296) referring to locomotive E. 10.003 of the German DB], also on the page with figure 454, with a new rubber mounted coupling developed by Siemens-Schuckert SSW and called the « Gummiringfederantrieb ». This coupling is shown in figure 477 and can be described as follows.

The body *1* of the traction motor is carried at three points *2* of the bogie frame and encircles the hollow shaft *5*; the latter rotates in the body by means of the ball-bearings *17*. On the ends of the hollow shaft are fixed the large gear wheels *4*, which have on the outer side of their rims six driving arms *6* passing through holes provided for this *purpose*, in the driving wheel discs. These driving arms *6* compress, in one direction or another according to the direction of travel, heavy rubber segments *8* (six per



1) Traction motor body.
2) arms for fixing motor I to bogie frame II.
3) pinion (fixed to armature shaft).
4) gear wheel.
5) hollow shaft carrying gear wheels and rotating in the motor body 1 by means of the ball bearings 17.
6) driving pins, six per wheel, fixed to the large gear wheel 4 and secured by 7.
7) outer ring of the coupling, fixing the pins 6 to the gear wheel 4.
8) rubber segments, six per wheel, compressed in one sense or the other (according to the direction of travel) by the driving pins 6.
9) inner ring of the coupling; this ring is fixed to the centre of the driving wheel and carries the six rubber segments 8 at the same time holding them against the wheel.
10) gear case (spur gears, bilateral).
11) leading cross member of bogie frame.
12) axleboxes (outside).
13) upper cross bearer of bogie frame to which are fixed two of the motor arms.
14) axle.
15) tubular hole, providing play between axle 14 and hollow shaft 5.
16) driving wheel spokes.
17) ball races for rotation of hollow shaft 5 in motor body 1.

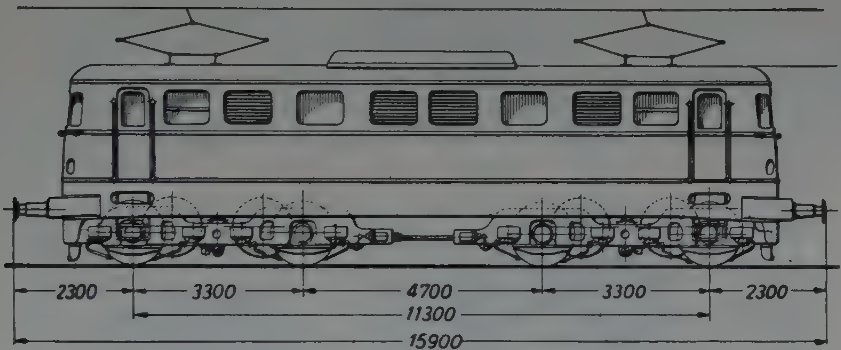
From « Glasers Annalen »

Fig. 477. — Diagram of coupling using rubber segments Siemens-Schuckert SSW known as the « Gummiringfederantrieb » fitted for four driving axles of the German Railways (Western) DB prototype locomotive E.10.003 (fig. 478).

The top shows a vertical section through AB at the bottom of the drawing.

The lower half of the bottom plan shows a horizontal section through the axle centre; the upper half a diagrammatic view from above, of half the bogie.

The coupling and the gears are bilateral and the complete driving axles are thus symmetrical in relation to the longitudinal centre line of the bogie.



From HENSCHEL.

Fig. 478. — Dimensioned sketch of German DB prototype locomotive No. E.10.003, 1952/3, type $B'_0B'_0$, E.10 class, built by Henschel and Siemens-Schuckert, with the new SSW rubber drive mechanism. The dimensions and arrangements are practically the same as for the prototype locomotive No. E.10.001 (end of Chapter III).

Fig. 479. — B_0B_0 locomotive, Gr. E 424, No. 102, Italian Railways FS, 3kV D.C., on a siding (see figs 308-312 *Vol. II*).

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wheel) which are held between an inner rim *9* and an outer rim *7*. The two rims *7* and *9* are theoretically concentric with the axle centre, but they have in relation to each other the play which is produced whilst running between the axle *14* and the bogie frame *11*.

Compression of the segments thus acts on the driving axle. We can only describe the mechanism for the moment; its behaviour can be commented on only after a year or two in service.

The DB prototype locomotive No. E. 10.003 was built by the Henschel & Sons

Works at Kassel (one of the oldest firms); electrical equipment was supplied by Siemens-Schuckert SSW. Figure 478 is a dimensioned sketch of this locomotive, the arrangement and dimensions of which class Gr. E. 424 (fig. 308 to 312). There were in service in the spring of 1953, 158 locomotives of this type, Nos. E. 424.001 to 158. These have the *Negri I* mechanism shown in figures 200-201 and

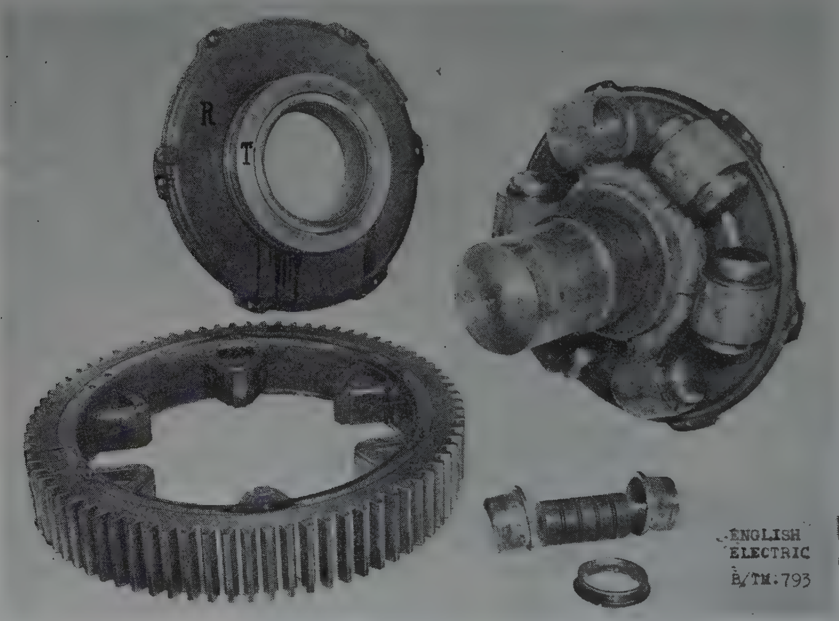

Fig. 480. — Components of quill-cup type mechanism totally enclosed in the gear wheel. The driving wheel is removed. For an electric motor coach of British Railways, Southern Region, 1953. Mechanism by English Electric Co.

R = gear wheel centre, carrying the geared rim and forming a stub hollow shaft which rotates on the bearings T in the gear case connected to the traction motor body.

T = roller bearings allowing movement of the geared rim mounted on the two symmetrical gear wheel centres which make up the stub hollow shaft.

Compare with lower part of fig. 481, showing the section of the axle.

will also be used for the prototype locomotive E. 10.001 which is mentioned towards the end of Chapter III.

A brief mention was made in the table following figure 444 of the relatively recent *Italian* locomotives shown in figure 479, a view of locomotive No. 102, 308-312 of *Vol. II.* Construction and equipment of these 158 locomotives was distributed between Breda, Ansaldo, Marelli, Brown Boveri (T.I.B.B.), Savigliano and Compagnia Generale d'Elettricità (CGE).

We show at the end of this chapter,

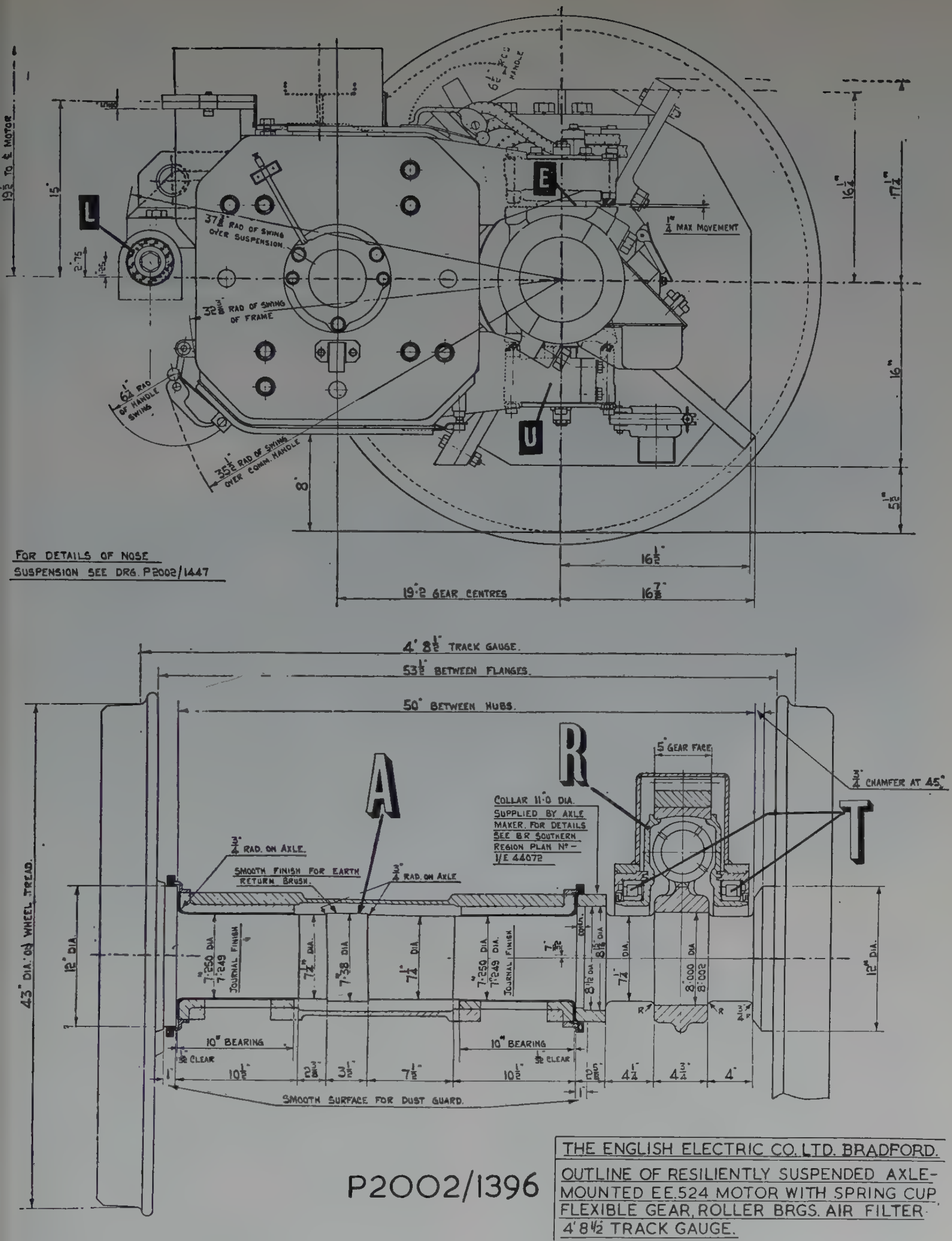

Fig. 481. — *Top.* Elevation of traction motor, with flexible nose suspension by upper E and lower U silent-blocks. L is the silent block supporting the nose of the motor.

Bottom. Section through axle centre, showing the arrangement of the quill cup mechanism. The centre of the gear wheel is keyed to the axle. R and T are the same as in Fig. 480. The complete gear wheel and internal drive mechanism is perfectly symmetrical to a plane perpendicular to the axle centre.

A = segment of axle periphery on which is located the earthing brush.

Note. — The journals and the axleboxes (outside) are not shown on this figure.

the total number of locomotives, motor coaches and motor coach sets of the Italian F.S. equipped with *Bianchi*, *Negri I* and *Negri II* axle drive mechanisms. At the same time, we will describe the F.S. Breda, rubber mechanism for the new high speed electric train sets ETR 301 and 302 of the F.S. mentioned on the page with figure 451, which were put into service on the 30th March 1953.

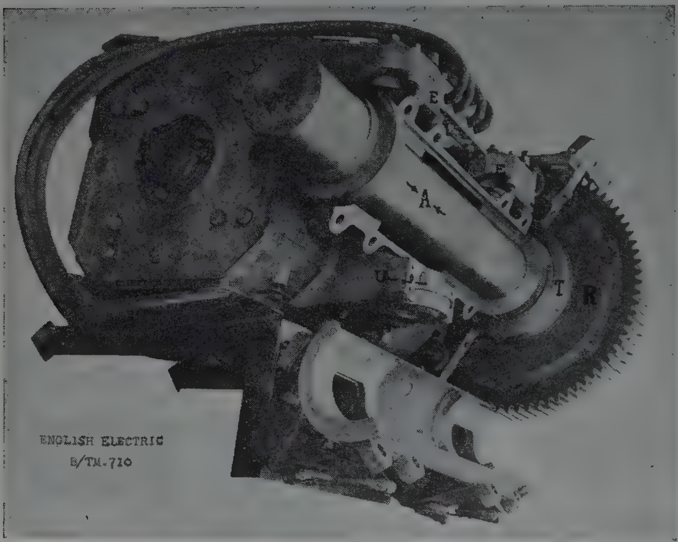

Fig. 482. — View of traction motor with lower bearing dropped to allow mounting of the axle of the motor.

A = as in fig. 481 (driving wheels removed).

R and T = as in figs 480 and 481 (bottom).

E and U = as in fig. 481 (top).

It is not yet known if the *Japanese* railways JNR (Japanese National Railways) — formerly Japanese Government Railways JGR —, see *Vol. I*, pp. 30-31 (352) or the South African Railways & Harbours SAR (353) have used either spring or rubber mechanism, but these two systems appear to use as a standard arrangement traction motors with nose suspension.

We will now describe a new mechanism developed in 1952 by the English Electric Company, Phoenix Works, Bradford. This is a special type of mechanism; it comprises a quill cup drive mechanism with rubber mounted springs, completely encased in the gear wheel and in addition the motor is nose suspended but rests on silent blocks, above and below, on a fixed hollow shaft in which the axle rotates.

The motor and drive assembly is thus made up of two component groups relatively independent of each other, viz:

1) the motor with arms taking the axle by means of the flexible parts, the pinion, the geared rim and the gear case; and

2) the axle with the gear wheel centre (in which is located the flexible drive

(352) See *A.F.A.F.*, No. 177, Nov.-Dec. 1952, pp. 154-157, with 8 views of locomotives Y. ONO.
(353) See *Vol. II*, p. 308 *(Congress Bulletin*, January 1950, p. 45).

mechanism) and the fixed hollow shaft which includes the bearings encircling the axle.

The complete arrangement is shown in figure 481; at the top are the motor and its resilient bearings E and U (on and under the fixed hollow shaft) and L (flexible link to the bogie frame); at the bottom, the fixed hollow shaft (shown along two-thirds of the axle) and the gear wheel on the stub hollow shaft (right).

facilitate dismantling the motor. The bearing body (including the fixed hollow shaft mentioned above) is supported independently of the motor itself (and therefore flexibly in relation to it) and follows the vertical (and transverse) movements of the axle.

The motor body includes, on the axle side, three arms, two of which are above the axle (on either side) and one below it (in the middle). The ends of these three arms are bored vertically to receive the flexible supports E and U (which are removable) each located between an outer and an inner grip (see figs. 482 and 485) with vertical rods which fix them in relation to the bearing body.

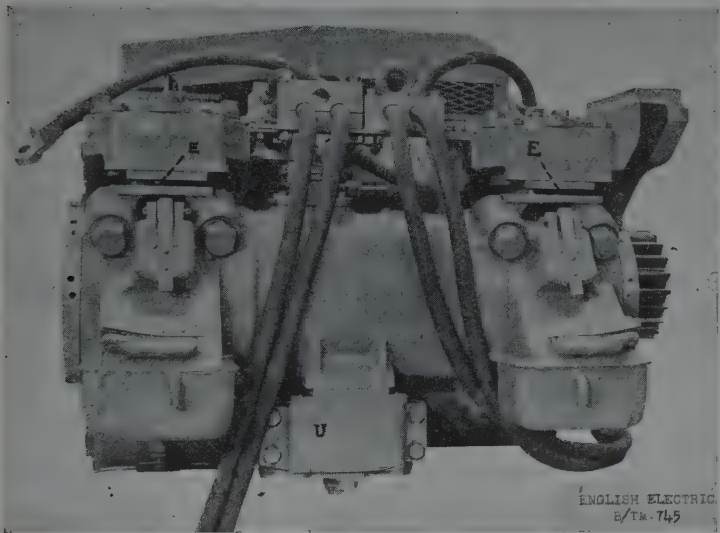

Fig. 483. — Traction motor of figs 481 (top) and 482, without axle. To the right is the pinion and above is the gear case (upper portion). E and U are as in figs. 481-484.

The motor is thus flexibly suspended in the bogie frame as well as in relation to the axle.

A detailed description of this motor and drive mechanism can be given, as follows (fig. 480 to 485):

The bearings-arms of the motor are fitted in a body casing divided obliquely, on a plane inclined at about 60^0 passing through the axle centre (see upper part of fig. 481 and fig. 482). The lower part of this bearing body is removable to

The grips (inner and outer) of each of the three flexible supports E and U, themselves comprise a silent block of conical shape (see fig. 485) which connects them flexibly, on the one hand to the motor body and on the other hand to

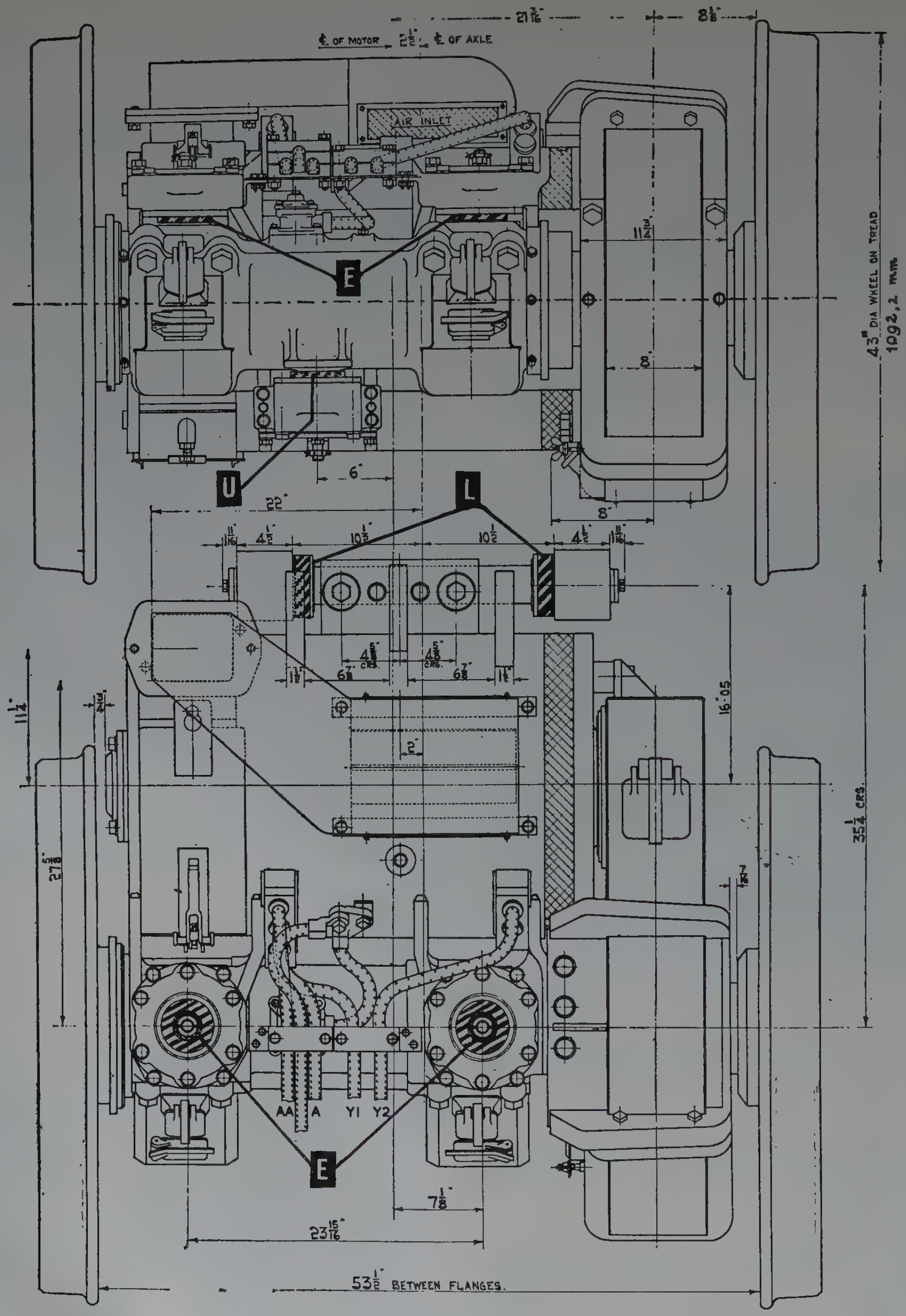

Fig. 484. — Complete driving axle assembly of fig. 481, front view (top) and plan view (bottom). E, J and L are as in figs. 481 (top) 482 and 483. — The heavy hatching shows the rubber parts. *Note*. — As in figures 481 and 482 the journals and axleboxes are not shown.

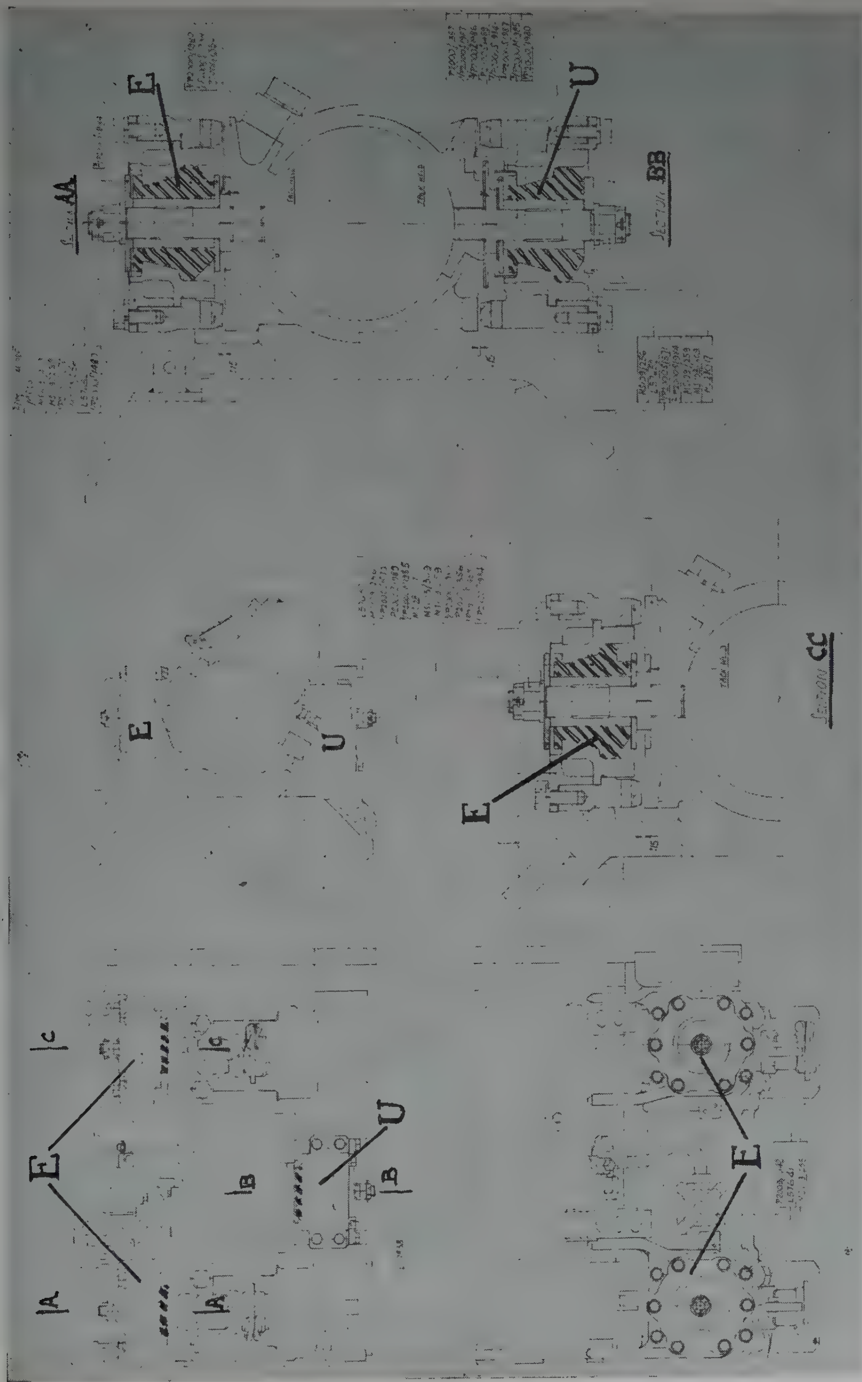

Fig. 485. — Complete motor suspended with axle supports; English Electric mechanism.
Compare figs. 481 (top) and 482-484.

the bearing body. In figures 481 (top), 484 and 485 the rubber components are marked with heavy cross hatching. The bottom flexible support U is held in position by a removable cap to facilitate dismantling the motor.

The side of the motor away from the axle (the « nose ») is provided with a shaft L (centre of fig. 484 high up in the bottom part of the figure) around which the motor can pivot in relation to the bogie frame; this shaft, solidly fixed to the motor, rests by its ends in the sockets (on either side of L) through silent blocks on the bogie frame. The motor can thus pivot slightly around the shaft L in which the silent blocks are also allowed a certain axial movement parallel to the axle centre).

The whole of this flexible assembly of the motor allows a vertical movement in relation to the axle of about 10 mm (25/64″) only.

Transverse and longitudinal displacements of the motor are limited by the flexibility of the details but the motor is well protected from shock in three directions, vertically, longitudinally, and transversely.

The flexible drive mechanism is composed, as we have stated, of a geared rim carried by two discs R rotating in the gear case by means of the bearings T (figs. 480, 481, bottom part, and 482); the case is also in two parts (figs. 481-483) so that the gear wheel may be exposed and is fixed by bolts through lugs provided for the *purpose* in the motor body (see fig. 484). The gear case and the geared rim are thus fixed in relation to the motor body and the pinion.

The centre of the gear wheel, keyed to the axle, is driven by six triangular thrust studs, solid with the inner surface of the gear rim. In the spaces between these studs are the springs (of rubber with four intermediate metal discs) each held between two cups and fixed by arms located radially around the periphery of the gear wheel centre. This mechanism is clearly shown in figure 480. There is thus a perfectly flexible transmission between the geared rim (driven by the pinion) and the axle. The surfaces in contact, triangular studs, and heads of the cups, are face-hardened and lubricated with graphited grease.

The complete motor assembly being flexibly suspended in relation to the axle, as well as the geared rim, the whole of the driving mechanism is independent of the deflection of the bogie frame, and it has been possible therefore to provide for a flexibility of about 10 mm (25/64″) only, conforming to that of the motor suspension. The suspension blocks have been fitted with plain bearings to facilitate the passage of current (A, figs. 481 and 482); this is important because of the relatively high amperage (D.C. 600- 750 V).

This English Electric mechanism is fitted to four axles of motor coach « Express Unit » class, No. 3059 of the Southern Region of the British Railways. Figure 486 shows a dimensioned sketch of this car, which is to be put into service during 1953, together with another of the same class, which will be fitted with an SLM-Winterthur mechanism which will be described in Chapter V.

(To be continued.)

[656 .255]

Operation and equipment of single lines carrying heavy traffic,

by M. MARCHAND,

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The International Railway Congress Association has already published many articles about single lines; the most recent were the reports by Messrs. VRIELYNCK and JACKSON, drawn up for the Rome Congress in 1950, at which the discussion of Question XV : « The signalling of single track lines on Light and Colonial Railways » aroused considerable argument.

As Mr. VRIELYNCK, Chairman and Special Reporter for Question XV, stressed at the beginning of his report, the methods of working and signalling single lines (and this also applies in the case of double) can be examined from various points of view : safety, economy of operation, and traffic capacity.

These various factors are closely interconnected and it is impossible to separate them completely. In the present article, however, we propose to examine the operating conditions and equipment of single lines, more particularly as regards capacity, and detail the methods likely to improve that.

Many Administrations in fact, having to meet a revival in traffic due to the development of their national economy, have wished to lighten the burden upon their traffic working arising from certain fully loaded single lines, and wish to dispense with, or at least postpone the necessity for doubling them, always a costly matter, and sometimes very expensive indeed in hilly countries.

Other Administrations on the contrary, and this applies to railway systems in certain highly developed countries (Europe, U.S.A.) find themselves in a quite different position. Owing to reductions in traffic, variations in the flow of trade, or even more especially because of the present tendency towards the concentration of the traffic on the most economical and best equipped routes, certain double lines are being progressively drained of traffic; the problem therefore arises, especially when track renewals become due, of reducing maintenance costs by the suppression of one of them, provided obviously that the one left can cope with the remaining traffic, which may still be considerable.

In both cases, it will be seen that a clear understanding of the economics of railway operation frequently implies increasing the actual capacity of a single line; the means employed to do so are many and concern numerous aspects of railway operation and engineering.

We do not propose to go into ele-

mentary principles, well known to all railway men, and will merely recall that the output of a single line depends essentially on the section between two consecutive crossing stations which is most difficult to operate (the longest in the case of a level line), and that one of the accepted methods of increasing the service is to reduce the length of the sections by increasing the number of crossing stations.

All railway men also know the advantages of a proper division of the line into more or less equal sections, as if they are unequal and consequently the train times differ a great deal in the various sections, on short ones much time will be lost in stations waiting to cross with a consequent increase in journey times; in other words, the train hours consumed along a single line depend on equal distribution of crossing points.

Finally, traffic capacity is directly linked up with train speeds. If the layout of the line makes it possible, it is an advantage to increase speeds, at least in the longer sections. Locomotive power and use of the automatic brake, which allows of high speeds on down gradients, are therefore important factors from the point of view of single line capacity.

These general principles more particularly concern the actual layout of the track and its equipment or the characteristics of the engines and rolling stock; to modify these is usually very expensive. In many cases therefore it is necessary to look for increased efficiency without having to alter the existing equipment.

In theory, the capacity of a single line should be half that of a double, where the distribution of the stations responsible for carrying out the block working would be the same as that of the crossing stations. This theoretical capacity, however, can only be achieved if the trains have not to stop at the crossing points and if such stops are not increased by the time taken to carry out the necessary signalling operations, besides which a considerable loss of capacity arises from the repercussions caused by irregular running as between opposing trains.

In other words, if we call N the daily number of trains corresponding to the maximum capacity, L the length of the worst section and V the average speed of the trains, total capacity can be expressed as a first approximation by the formula

$$N = k \frac{V}{L}$$

k being the coefficient of proportionality, which is always less than unity, having regard to the losses above mentioned. To improve the output of a single line without modifying its layout means therefore that the factor k must be improved, i.e. useless stops or reductions of speed must be avoided, and care taken that no time is lost at any point, while in general the service is made more flexible and the way it is worked carefully checked. In particular, it is essential in the case of lines not carrying exclusively stopping trains, that through trains should be able to pass stations without having to slow down. It is even desirable when trains cross that the second should be able to run through at speed, making what is known as a « non-stop crossing ».

All these objectives can be achieved by the application of suitable operating methods and the improvements offered by modern signalling and telephone practice which make it possible to increase the operating efficiency at very little cost, whilst giving additional guarantees as regards safety.

In this special but extensive field, the following go to make up the complete picture :

— the operating regulations;

— electric interlocking between stations (single line block);

— station interlocking installations (operation of points and signals);

— traffic control (in the usual sense);

— centralised traffic control (remote control of points and signals).

In what follows, we have taken these items in this order and endeavoured to analyse and summarise as objectively as possible the chief methods, operating and technical, open to railway officers to select. To keep within the actual and practical, we have omitted such innovations as the application of radio-telephony between stations and trains, or between the traffic controller and the trains, on which opinion requires still be reserved as sufficient experience has not yet been obtained with them.

Operating regulations for single lines.

This expression comprises the whole of the measures taken to prevent opposing trains from meeting head on, which differ considerably from one railway to another.

Their principles are based on recognised rules, originally applied to prevent collisions : pilotman, train staff, etc., or the observance of crossing points as laid down in the timetables; in many countries the telegraph or telephone service has been used to diminish the inevitable inflexibility of such rules and made it possible to carry out certain operations (modification of crossing points laid down in the timetables) by agreement between the staff concerned.

Certain railways have even considered the telephone reliable enough to rest safety on its systematic use. This is the case in particular when the rules lay down that permission for a train to proceed shall be asked for from station to station for each train.

As far as carrying this out is concerned, the application of the regulations is effected either by the train crew or the station staff, or simultaneously by both, as the case may be.

Is it possible to decide on the respective value of such regulations and select those which best answer to traffic operating requirements ?

From the safety point of view, which should predominate, it is particularly difficult to do this. When presiding over the discussions in connection with Question XV at the Rome Congress, Mr. VRIELYNCK stated, and the discussions confirmed this, that each railway thinks its own regulations and signalling methods are safest.

It must be recognised that regulations can be influenced by the characteristics of the traffic, which may differ considerably from one line to another; for

example the needs and requirements of a heavily loaded line cannot be the same as those of a line with little traffic, so that many railways have adopted different regulations for the two types; the regulations may also depend on many other factors, especially the quality and even the temperament of the staff responsible for applying them; in this connection the safety factor of a regulation depends to a large extent upon the degree to which it is respected, and consequently upon the discipline of the staff carrying it out.

As regards the capacity of heavily loaded routes, the various types of regulations for working single lines have their own characteristics, which we shall proceed to analyse and compare.

If, as we have already said, most of the railways are very attached to their own regulations, it appears that they will nevertheless agree upon one point : this is that operating regulations based *on the train crews respecting the working timetable are not conducive to efficient working* and hence to satisfactory traffic capacity.

This system is applied above all in the United States where it includes :

— on the one hand, a classification of the different types of trains, those of inferior class having to accord those of a superior class the right of way by getting out of their path in good time;

— on the other hand, the possibility of the train dispatcher allowing by a « train order » a train to proceed as far as a given crossing point if the train of superior class is late.

These operations necessary to safe working being carried out by the train crews, the railways concerned have been able to avoid having permanent staff on duty at the crossing stations, with the advantage of being able to multiply them without increasing operating costs. This also avoids the difficulties associated with stationing staff at places on lines running through semi-desert districts or sparsely populated regions; the system, however, has serious drawbacks as the trains have to make frequent stops to enable the train crews of the inferior trains to communicate with the dispatcher; in addition the crossings or « meets » as they are termed in America, involve a considerable waste of time, since, as there is no station staff, the slow trains have to stop before and after each station to enable the guard to work the points.

Moreover, the United States railways which at one time had such a system in more or less general use, are now giving it up on the more important lines, but since they did not wish to make any changes, or so it appears, in their train crews or staffs at the stations, they have gone over to centralised traffic control (C.T.C.).

Consequently, apart from installations including centralised control of the stations, it can be affirmed that flexibility of operation requires the use of station staff to work the points and signals; as such staff is intended to assure the safety of the trains, the application of the operating regulations then becomes the direct responsibility of the stationmasters.

The regulations which can be applied

in this case can be classified under three main types :

— the train staff;

— adhering to the working timetable;

— asking « Is line clear ? » or offering and accepting each train.

The train-staff.

The train-staff system is widely used throughout the Anglo-Saxon railways; the British Isles and Dominions, which state they find it very satisfactory; on the contrary the railways on the continent of Europe hardly ever use this method. Theoretically, the train-staff is more than a token of safety. It is a derivative of interlocking since it results in an actual positive interdependence between stations.

The fact that a station is in possession of the train-staff gives it in principle the right to send on a train, and this right is in addition checked by its driver, who must be given or shown the staff; the staff is also a type of route locking control since it is only when the train carrying it reaches the following station that another can be sent in the opposite direction; in theory, therefore, it is a safeguard against mistakes on the part of a station which might otherwise send off a train before one coming towards it had arrived.

Finally, the train staff makes it possible to continue to run the trains even when there is a total breakdown of telephonic communication between stations; the service may perhaps be worse but there is no complete stoppage.

However, as regards the running of the service and capacity of the line, the train-staff appears to have serious drawbacks, though we will not stress these unduly as the system is little known in Europe.

The train-staff system has a certain rigidity due to the fact that only the station which has the train-staff at a given moment can send on a train.

The result is that when a station has done so, it cannot send on another until it has accepted one from the opposite direction. The order in which the trains run is thus fixed for a relatively long period; the electric train-staff, however, with which we shall deal later, makes it possible to eliminate this serious drawback.

On the other hand, the exchange of the train-staff between passing trains is liable to involve certain drawbacks which may prove particularly serious in the case of stations of average or large size, with separate passenger and goods stations, separated one from the other. This means that the train-staff has either to be transferred from one to the other, or trains must stop outside the station so that the train-staff can be picked up or delivered.

Finally, if the train-staff, which must be handed to, or at least shown to, the driver of the train before he can enter a section may be a practical arrangement where trains stop at every station, it does not seem possible to use it where trains run through without stopping. Certain railways have indeed equipped their locomotives and stations with special equipment enabling the train-staff to be picked up and delivered by trains in passing,

but we consider this to be a palliative and not a solution to the problem of through trains.

Running to the working timetable.

This term has led to a certain amount of confusion. It appears that some imagine this safety system to be based on a strict adherence to the timetables; this cannot be so, as no railway can pretend to run all its trains exactly on time. It is therefore necessary to define very clearly that it only means respecting the crossing points laid down in the working timetable, which then assumes the character of a safety document.

For example if it lays down that train A shall pass train B at 8.32 a.m. at station X, the stationmaster is responsible for seeing that it does so, and must not send on train A before train B arrives, and reciprocally. Adhering to this rule obviously is in itself a guarantee of safety, even if the timetables are not scrupulously observed as the crossing need not take place at exactly 8.32 a.m.

Naturally, the stationmasters must be kept advised of the running of special or conditional trains in good time, and before such trains reach the single track section; this is the responsibility of the traffic regulator where there is one.

In case of train delays, the service can be made more flexible by telephone agreements between stationmasters; in the above example, if train A is late, it is possible to alter the crossing place, i.e. to change it from station X to another station Y, which then becomes responsible for seeing that the crossing takes place.

In this way it is possible to limit the effects on the entire service caused by a train being late while reserving telephone messages concerning the safety of the working to those cases where there has been some disturbance to the traffic. This means that telephone messages may be exchanged but should the telephone be out of order the traffic is not stopped completely in consequence and the trains can continue running.

It may be thought from this outline explanation that safety rests entirely on the stationmaster who is responsible for the crossing laid down in the working timetable. However, to avoid the consequences that can follow even a single mistake, most railways using this system have introduced various additional safety precautions, either by requiring the train crew to check that the arrangements relative to crossings laid down in the working timetable are properly respected (Switzerland) or, when the telephone is functioning, in requiring the two adjoining stationmasters to exchange messages before any train is sent away (France).

From the point of view of the actual running, the trains must obey the instructions given by the signals at the stations, which of course implies thoroughly good discipline on the part of all concerned.

The running of a train through a station without stopping and the carrying out of a crossing movement in which the second train does so, thus raises no difficulties, so far as the regulations call for no strict checking of the crossing points by the train crews themselves.

On the other hand, by their very

nature, regulations based on carrying out the working timetable have a tendency to cause those concerned to observe the order of the trains given therein and therefore to apply very strictly an instruction which is in fact nothing but the plan of an ideal service. These regulations combine together the best conditions for obtaining a high working capacity, it being understood that the train crews are actually able generally speaking to follow the working timetable properly. On lines subject to much interference with the prescribed working, arising from trains being continually late, or where the irregular nature of the traffic leads to numerous additional trains having to be run, the formalities necessary to regulate these disturbances risk becoming too complex and detract from the simplicity and efficacity of the system.

Offering and accepting a train or asking « Is line clear ? ».

This system of regulations is based on the exclusive use of the telephone or telegraph. Before authorising a train to enter a section, the stationmaster must verify that the line is unoccupied and obtain from the stationmaster at the next station an assurance that no train will be sent off in the opposite direction.

These regulations can be used with, or be incorporated in, the rules for telephone block covering the passing of trains running in the same direction.

As under the preceding method, the driver acts solely on the signal indications at stations, which allows of through non-stop running without difficulty.

This system of offering and accepting a train, called also asking « Is line clear ? » puts a good deal of work on the station staff, as it obliges them to exchange messages for every train, and the time that can be lost when effecting crossing movements is not negligible, especially in the case of those railways which insist on the use of the telegraph in order to retain a record of messages sent and received. This system therefore appears little to be recommended for lines carrying considerable traffic. In fact, it appears often to be applied not as the actual working method itself but simply to give additional safety.

Finally as it is based exclusively on the use of the telephone, it is open to misunderstanding and there is the risk of the whole working becoming stopped if communication breaks down unless some appropriate means are provided to avoid this.

* * *

Remarks.

This examination of the various methods of working single lines has been directed to the fundamental principles which must be applied in order to ensure the safe running of trains travelling in opposite directions, but it is seldom that the regulations actually in force are based on these alone. In most cases, they represent a combination of principles and this is justified for the following reasons : — either by a wish to obtain the advantages of one or the other method, as for example in France where the trains run normally on the system of observing the working timetable, offering and accepting being used only for

movements not laid down therein, or it may be to obviate certain difficulties inherent in the main working arrangements, as for example by introducing offering and accepting on a line worked by train-staff when it becomes necessary to send a train towards the station which happens to be in possession of the staff, or when the reverse process is called for, that is introducing train-staff working on a line operated by offering and accepting of trains when telephone communication has failed. Something of the kind also may be applied as an additional safety precaution.

Moreover, these rules intended to prevent the danger of head-on collisions, peculiar to single lines, require to be completed by others designed to prevent trains overtaking each other, that is to say to provide a space interval between following trains, as is done on double lines and they can, as in the latter case, be based either on maintaining a time interval between two following trains in the same direction or on the application of a minimum space interval by means of block posts established along the line and connected telephonically. These block posts maintain an interval of one block section between following trains, and this method is called « block working » or « block telegraph working ».

Many Railways have adopted this arrangement which offers much greater safety than time interval working. It is admittedly a little less flexible especially where trains travel at low speeds, and it may be necessary in that case to shorten the distance between block posts and install intermediate ones between stations in order to get enough capacity on the single line. Although not so effective as the provision of additional crossing places these block posts can appreciably facilitate the working on lines where there is the possibility of trains having to be sent after each other at short intervals. Similar considerations are involved when the block working is effected by means of interlocked signals — lock-and-block working — and it is desirable as will be seen later, that single line block systems should be designed so as to permit of intermediate block posts being installed.

Electric interlocking between stations.

The single line regulations outlined above are based exclusively on the staff concerned applying agreed rules and call for no equipment beyond a telegraph or telephone circuit. Many sections of line are worked in this manner. Here, however, as in other matters of signalling practice, many Railways have considered it essential to introduce on certain of their lines interlocking arrangements between stations to facilitate the work of those in charge and eliminate risk of mistakes, the probability of which increases rapidly with the intensity of the traffic and the irregularity of the movements occurring in it.

This is one of the most characteristic instances of the connection between the capacity and safety of a line and in the writer's opinion although the interlocking devices in question do not, generally speaking, increase the former, they need to be applied on lines carrying much traffic or those where the train move-

ments are subject at all frequently to irregularity.

The existence of these devices does not at all diminish the importance of the rules already dealt with above, because for one thing they are merely a positive form of carrying them out, and further they are to be looked on only as additional safety precautions which do not eliminate the usual traffic operating regulations but are superimposed on them and strengthen their effectiveness.

The various arrangements which have been constructed are somewhat numerous, but may be divided into two main classes :

— electric train staff apparatus, and

— single line interlocking block installations.

The *electric train-staff system* comprises electrical instruments containing a number of staffs, the instruments between adjoining stations being connected together electrically in pairs in such a manner that at a given moment one staff — and one only — can be withdrawn by one or the other station of the same section; all the remaining staffs then becoming locked in the instruments until such time as the one which has been withdrawn has been replaced in one or the other of the pair of instruments to which it belongs.

The electric train-staff apparatus eliminates one of the disadvantages already mentioned as applying to the ordinary simple train staff, for if the section is unoccupied a train may be dispatched from either end at will. It therefore provides more flexible working than the ordinary staff, for it is possible easily to put an unexpected train movement into operation and especially to send any engineer's department vehicles immediately they are asked for. Safety is also increased by this arrangement as every train carries a staff.

Finally, certain somewhat complex arrangements involving a mixed type of working, with train-staffs for long and short sections, allow of economising by closing temporarily and switching out certain stations.

The electric train-staff, however, merely by itself, does not appear to solve the problem of sending trains in the same direction at short intervals, and also possesses the disadvantage of necessitating the use of special apparatus for receiving and delivering staffs when trains run through stations at speed. From this point of view as soon as an electric interlocking circuit is established between stations it would appear more advisable to make it control the station signals, so that safety rests, as on double lines, on their observance. This is achieved in the single line interlocking block or lock-and-block.

Single line block apparatus.

If the electric train-staff system has been applied by those railways whose regulations normally require a train-staff to be used, the single line block has been adopted more especially by those basing their working on the observance of the working timetable, or the system of offering and accepting a train, and this implies the use of signals to govern trains entering on a single line section.

This form of block compels obedience to the rules for working the station starting signals designed to prevent two trains being sent off in opposite directions. For this purpose, each starting signal is normally locked at danger by an electric lock and this can only be released if :

— there is no train in the section, and

— the opposing starting signal at the next station is locked at danger.

The proving of these conditions is set in operation by actuating small push buttons or switch handles. On some lines, this has to be done by the stationmasters at each end of a section acting together, which corresponds in fact to the system of offering and accepting a train. On others, only the stationmaster at the entering end of the section needs to take action and this avoids the other stationmaster having to be standing near the block apparatus when a train is to be sent towards him. In that case, the working is said to be effected on the « free dispatch » principle.

In all cases, however, from the moment when one of the stations is able to clear its starting signal the other station obviously can no longer send a train away since the starting signal there is locked at danger as well as the distant or other approach signal in rear.

There is thus an actual *directional interlocking effect* but it is essential that it should be maintained all the time the train is travelling through the section. To effect this the *block interlocking* as on double lines makes it obligatory to block the line when a train leaves and clear it again behind the train when it arrives at the end of the section, and the stationmaster there has seen that it is complete.

The interlocking prevents the starting signal at the sending station and the one at the other end of the section from being cleared while the section is occupied, so that both opposing and following movements are safeguarded.

It is to be noted that it is comparatively easy to provide intermediate block points with the signals controlled by the block circuits, enabling trains to follow each other at close intervals. On the other hand, it is equally easy to close a station B, to save staff during slack periods. Operating a closing switch puts the block out of circuit and the trains are then worked between A and C direct.

The actual construction and working of these interlocking arrangements vary considerably between the different installations and it would take us too far to describe the numerous designs met with. In the *Congress Bulletin* for October 1954 will be found the description by M. J. WALTER of the single line block of the S.N.C.F. which is of recent design and formed entirely of relay equipment working on « coded » circuits.

Control of block apparatus by the train.

In the case of double line block, apparatus such as that just described for single lines guarantees safety only to the extent that those responsible for working it carry out correctly the various blocking and clearing operations when trains depart and arrive. If, for example, the stationmaster or signalman should omit to put his signal to danger

behind a departing train it would be possible for it to be overtaken by another running in the same direction and if — which is very much more serious — he is able to put his signal to danger without actually blocking the section — without signalling « train on line » correctly — there is then nothing to prevent the next station from sending off an opposing train with risk of a head-on collision. The same thing applies should a station clear back — give « train out of section » — at the wrong time before a train running in the section actually arrives.

To eliminate the risk of such forgetfulness or mistake some single line block installations include treadles (rail-contacts) or track circuit arrangements which release the apparatus and allow certain operations to be performed only when the train has actually passed and left the block section. They give the same security as regards the working between stations that route locking does in modern power interlocking areas, it being understood that the apparatus is so devised that shunting movements outside station facing points will have no harmful effect on the block working.

Some Railways have applied for this purpose the same principle as is met with in route locking by having rail-contacts or treadles at the entering and leaving end of the section (see fig. 1). There are either one or two of them near the starting signal which return it automatically to danger and bring about the locking up of the section. There is in addition another, or releasing treadle at the end of the section — at the entrance to the station — which must be actuated before it is possible to clear back on the block to the station in rear.

Certain Railways, however, have adopted continuous track circuiting. The occupation of the track either puts the starting signal to danger or proves it is in that position and locks it and makes it impossible to give « line clear »

Diagram No. 1. **Single line block installation with treadle control.**

Gare X = station X. — Zone de manœuvre = limit of shunting. — Gare Y = station Y.

A and B — Starting signals, common to through and loop lines.
These signals are not cleared for shunt movements which are allowed to pass them at danger.

a and e — Departure treadles.
A departing train returns the starting signal to danger by actuating treadle *a* and locks up the block by working treadle *e*.

S — Arrival treadles.
With a train travelling from X to Y, the latter station cannot clear back for it on the block until the train has actuated the arrival treadle S at the approach to the station.

while this condition obtains. This is to be regarded as more complete than the system using treadles because it remains effective even where, from breakage of a coupling, part of a train remains left in a section and it dispenses with having to see that the train is complete before clearing back for it. As far as the writer is aware it has not been much applied as it is more involved than the other arrangements.

Moreover, directly it is decided to install track circuiting throughout the line, it is little less costly to put in automatic signalling, and it then becomes attractive from the point of view of increasing capacity, to provide short signalling sections which will allow of trains following one another at close intervals.

Several installations of this sort have been made, notably in Japan, but they are not particularly numerous, the advantages from the point of view of safety and increased capacity hardly justifying the high costs involved.

On the other hand, something like this is necessary in all cases of automatic or remote control (C.T.C.) working, the purpose of which is to eliminate signalling staff at stations which of course excludes the use of manual block apparatus.

Station Signalling and Interlocking. (Equipment of points and signals.)

The station staff has not only to carry out the single line block regulations but also to operate the points and signals and set up the route for arriving and departing trains, or those requiring to run through non-stop.

The track layout, the controlling of the points and signals, and the method of working them may have an appreciable influence on the capacity of the station. Designed in the first place to ensure safe working, they can be so arranged as to eliminate any need for reducing speed and loss of time and give the maximum degree of flexibility in train operation. A quick review of this matter will therefore be taken from this point of view.

Track layout.

Single line stations have at least two main tracks to allow of trains crossing or passing each other by overtaking, and they can be arranged in two principal ways which we will term respectively :

— stations having lines each with its own direction of traffic and no through direct line;

— stations where the lines can be used for either direction of traffic, one being a through line.

In layouts of the first type, the stations are really double line sections inserted into the single line; this is why on those railways using left-hand running, the trains always take the line to the left on entering a station (see diagram fig. 2 *a*). These stations are therefore known as « left-handed » stations (« gares à voie de gauche »).

In this type of station, the trains meet at least one pair of points set for the turnout. (In the case of fig. 2 *a*, this of course will be those at the leaving end of the station). This means that they must observe an appreciable speed reduc-

tion of the order of 30 to 45 km (18 to 27 miles)/h, [1], according to the type of points. This is inconvenient when trains pass without stopping.

The points standing always for the left-hand line for arriving trains whether they are crossing another or not, the staff are only concerned with working those at the outgoing end of the station for a train unless they are arranged to be trailable; which dispenses with any action on their part. These trailable arrangements are well-known and consist of counterweights or spring devices which automatically return the points to their normal position behind a train which has taken them trailing.

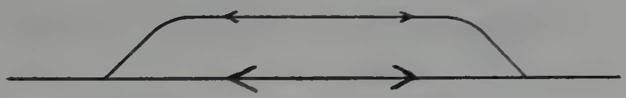
In the direct running type of station (diagram fig. 2 *b*) one of the lines is laid straight through and used normally for all trains in either direction, the other line, called the loop, being used only for crossing or overtaking.

The important feature of this working is that no speed reduction is required on the part of non-stop trains; all that is necessary is to fit bolting arrangements to the facing points to lock them in position for a train to run straight through.

For this reason most Railways which operate heavily worked single lines over which through trains run adopt this type of layout, the only one we shall consider in what follows.

Diagram No. 2. **Single line stations.**

a) left-hand station.



b) station with direct, or through, line.

Operation of points.

The facing points stand normally for the direct route, or through line, and are bolted in that position. There is no need to operate them except when a crossing has to be effected.

Many Railways are satisfied to operate these points locally on the ground and interlock them with the signals by key locking, while others fairly generally use interlocked levers, located either in a signal box at each end of the station or, what makes less demands from the staff point of view, from a frame by the main building.

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(1) It is to be noted that there are in France stations of this class where owing to the use of long lead points it is possible to pass over them at 60 km (37 miles)/h.

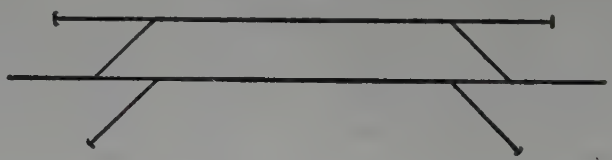
When the points are locally operated, it is good practice to make the facing points trailable, as at stations of the « left-hand » type, as it allows of crossings being effected with great rapidity and the minimum of staff. It is then sufficient before a train arrives to :

— unbolt and reverse one pair of points to receive the train into the loop;

— unbolt the other pair, while keeping them for the through line.

These latter points are clearly not in the right position for the departing train but the fact that they are trailable means that the staff have not to concern themselves with them when a crossing occurs. All they have to do after a train has left is to return the points to their normal position and ensure that the through route is set up and the bolting is again operative.

Diagram No. 3. **Stations with trap points.**



We may note here that making the points trailable is not compatible with having, as do certain Railways, the tracks so arranged that there are trap points at the ends of the station (diagram fig. 3) in order to keep quite distinct from each other the routes of two trains which are to cross and prevent one from being collided with should the other fail to stop at the correct place. These arrangements although not excluding all risk of mishap, are not greatly favoured owing to their complexity.

So far we have considered only ordinary crossings between two trains and have seen that with the entering points made trailable the staff has only to concern itself with them before or after a crossing takes place. Except on lines where stations are very close together, the time available for carrying this out is generally sufficient to enable them to go down to the points and actuate them locally.

This no longer applies, however, when it is a question of a crossing in which the second train has to run through without stopping because it is necessary, before it does so, to return to normal the points that were reversed for the arrival of the first train, then to return to the station with their locking key in order to allow of the signals being cleared for the second train. The time to be allowed in the timetable between the arrival of the first train and the passing of the second must take account of that required by the man concerned to go from the points to the station.

It is possible to make the working considerably more flexible by either using key transmitters, the use of which, however necessitates employing two men,

or by operating the facing points and their bolts from a distance.

From the traffic operating point of view, operating from a distance is better but involves a good deal of equipment because the points often are at some distance — several hundred yards — from the station building and because the programme to be met is a complex one. Apart from the actual working of the points and bolts, which must as a rule be arranged to permit of local operation as well, to facilitate handling certain trains, such as pick-up goods, it is advisable to consider using certain subsidiary equipment, such as electric detection of both points and bolts, locking bars, treadles, or track circuit to prevent irregular operation under a train or to verify if the rear of one on the loop is clear of the through line fouling point, and so on.

As illustrating the progress accomplished in operating points mechanically by the double wire system, we may point out that equipment is now obtainable capable of doing that up to 700 m (765 yards) very satisfactorily. This is less costly than electrical operation.

Signalling of stations.

The signals at single line stations must give the driver all the indications necessary to enable a train to arrive or run through in complete safety. They must be able to give a stop indication if entry to the station cannot be allowed, as when shunting is in progress, and also a reduced speed indication when a train is to be received in a loop.

As regards departing trains, stop signals need to be provided to mark the point beyond which a train must not go, especially when a crossing is being effected. They are only cleared to authorise a train to leave when the regulations and block interlocking permit of that.

Both stop and reduced speed indications are preceded by distant or approach signals as the regulations in force prescribe.

Enquiries made by the reporters for Question XV of the Rome Congress brought out the great diversity of signals met with at single line stations, largely a result of the different ideas obtaining regarding the meaning and use of signals and of the legitimate wish of many Railways to avoid too complicated signalling. If, in certain exceptional cases, the signalling of a station might ordinarily call for up to a dozen signals, many lines have endeavoured to reduce this figure. For example, some are satisfied to have a common starting signal for both direct and loop lines.

To obtain flexible operation, it is important to have the least possible hindrance to train movements. Fast trains must be able to run through without reducing speed provided, of course, the points are properly bolted. On the other hand, trains received on the loop or on the direct through line with unbolted points must be able to enter the station without stopping at the maximum speed such points will pemit of.

We should mention in speaking of the rapid carrying out of crossing movements, the appreciable disadvantages resulting from the rule laid down by

some Railways that two crossing trains should only be allowed to enter a station one after the other, the signals for the second not being cleared until the first train has arrived in the station.

The timetable must in this case allow a fairly appreciable interval between the two arrival times, and it often happens that a little delay to the first train causes an unnecessary stop to the second outside the station and a not inappreciable loss of time in having to restart.

We are not overlooking the fact that this arrangement is intended essentially to obviate the risk of a train over-running the starting signal but our view, based on the long experience of the French Railways both on double and single lines, is that it is possible when all trains have continuous brakes to obtain sufficiently good and reliable action on the part of drivers as to render this risk negligible. In that case a very considerable flexibility of working is obtained as a consequence of being able to receive two trains simultaneously.

The application of the principles just set forth allows of an appreciable reduction in time lost when crossings take place.

As regards crossings effected in stations where the facing points are trailable and the reception of two trains simultaneously is authorised, the minimum time which needs to elapse between the arrival and departure of the trains is that required to operate the block, that is to say to clear back and actuate the apparatus which releases the starting signal, for each of the adjoining block sections. This only takes a very short time, not exceeding one to two minutes.

In the case of crossings where the second train runs through non-stop, at stations with central interlocking apparatus for working the points and signals a correspondingly small interval is required for :

— returning the facing points concerned to normal;

— clearing back and operating the block to allow of the home and distant signals for the second train being cleared.

Taking into account the time necessary to ensure that the fast train shall find all signals at clear for it, the minimum interval required between the arrival of the first train and passing of the second is of the order of three minutes.

* * *

Traffic control or train dispatching.

This type of working originated in America where it was essential to advise the train guards what the traffic position was. To do that, central control or « dispatching » offices were established equipped with special telephonic facilities allowing the « dispatcher » to communicate with all the crossing places along the line over a single line wire circuit and selective calling apparatus. This form of working was a necessary corollary of the American system of traffic working and proved particularly effective from the operating point of view as it gave the dispatchers an exact general view of the positions of all trains in their areas.

A number of other railway systems, although not under the same necessity, as their working regulations were put into effect by the stationmasters, nevertheless wished to benefit by the advantages it offered in keeping traffic moving by providing the traffic controller with all the information relating to the actual state of the traffic. The existence of this, as it were, information centre has allowed the stationmasters to do their work with more precision and take account of the least incidents or delays when making their decisions regarding shunting movements and putting trains into sidings.

Traffic control post.

It came to be seen, however, that the controller was better able than the stationmasters to appreciate the consequences of incidents as affecting the entire train running and by a natural evolution, he tended to become more and more their adviser, and on their own initiative they asked for his views. In this way, the arrangement developed into a real controlling organisation, taking on the one hand all the decisions necessitated by such incidents and on the other hand watching over the working and dealing at once with any mistakes or negligence adversely affecting the traffic.

This is the position at which many Railways have arrived and it is indisputable that installing traffic control has allowed of the working being very appreciably improved and the upper limit of capacity being correspondingly raised. Some Railways, we think, especially in Switzerland, have succeeded in attaining really remarkable traffic carrying capacity without having recourse to such control, but it would appear that there it is a question of lines where the regularity of the working is quite remarkable, doubtless in consequence of the use of electric traction and a high proportion of the traffic being passenger trains, combined with a very high standard of discipline and efficiency among the traffic staff.

However, on all lines where traffic is heavy, whether double or single, and where the working is subject to disturbances such as a failure of the means of traction, repercussions from the delays arising with long distance trains, irregular movement of goods traffic, etc., the control system always allows of the efficiency being improved, either by the obtaining of increased capacity or a much higher degree of economy in the working.

In this latter connection, we may mention the case of certain French lines carrying a moderate traffic and provided with control but where traffic has noticeably fallen off, so much so that the question was raised whether the maintenance of the control staff was any longer justified.

The reply of the Operating Department was unanimously in favour of retaining the control, which had effected noteworthy improvements on the lines concerned as regards the times to be allowed to train working in the stations and the effective allocation of train running and overall journey times. It was considered that this quality of the service could not be maintained except by retaining the control, and were it to be abolished it would become impossible to avoid a diminution in the discipline of the staff running the trains and a progressive lowering of the quality of the service which was, all things considered, more costly to bear than the maintenance of the control.

All that we have just said from the general point of view is still truer in the case of single lines in consequence of the interdependence of opposing trains. The intelligent action of a controller can regulate the working in such a manner as to obviate the risk of loss of efficiency at key points and especially at the ends of long sections, or those most difficult to work which, as mentioned above,

determine the capacity of a line as a whole.

We can therefore assert that whatever may be the equipment of a single line, whether it has block apparatus or not, modern station equipment or not, one of the most effective measures in the endeavour to improve its capacity is first to set up traffic control.

As regards its practical application on single lines, with staff on duty at the stations the traffic controller's functions can take very different forms.

Certain Railways have developed their ideas on this matter in agreement with those obtaining on American lines and gone so far as to give the controller the duty of ensuring safe working, while giving also to the stations instructions necessary to prevent rear or head-on collisions, while others have gone even further still by making the train crews take part in controlling the running, the station staff then having only to effect communication as between the controller and the train crews.

In both these cases, the station staff act merely as pointsmen and telephone operators, but it would appear that such methods which rest the safety of the working on a single person, the controller, cannot but lead to the risk of that official being overworked, and they appear to be applicable only in cases of medium or light traffic.

For heavily worked lines, on the other hand, it appears desirable that the controller's function should be limited to dealing with traffic movements only and have nothing to do with providing for their safety, the application of the rules governing that being left to the staff at the stations. For example, should the controller decide to transfer a crossing from, say, station A to station B, it is the duty of the respective stationmasters to ensure that the relevant rules are properly carried out, either by effecting the required exchange of messages resulting from the changing of the crossing place, and to agree together on carrying out the process of offering and accepting, or on those lines where the block is in use, by operating the apparatus in the prescribed manner.

Automatic and remote control working.

Automatic and remote control installations appear to have been designed hitherto entirely with the idea of abolishing, partly or completely, the station staff, and to have sprung from the desire to effect economies in working.

For the same track layout, they do not bring any considerable increase in capacity as compared with installations of the well-known type using local operation for the points and signals; but as they allow of new crossing stations being opened without having to increase working costs they possess the inherent possibility of improving capacity.

We will refer first of all to the *automatic working* used on single lines by the Belgian Light Railways Company. The stations are all of the same type arranged for right-hand running, the facing points standing normally for the right-hand line and being trailable. Drivers are required to pass over them at low speed and themselves see that they are properly closed before doing so.

As regards the automatic single line signalling, this is arranged on what we have called the « free dispatch » principle, which in this case means that setting up the direction and control and clearing of the relative starting signal takes place automatically as a train arrives, by means of an approach clearing circuit.

This arrangement necessitates all trains slowing down when passing a station and in addition is suited only to lines where the traffic working is very regular or where all trains are regarded as of equal importance, since if two trains approach a section at the same time priority is given to the one first actuating the approach control circuit.

In the much more general case of lines run over by fast trains of different classes, it is not possible to consider abolishing station staff in this way. This can only be done by adopting remote control for the points and signals at stations, for it is necessary to be able to coordinate the train working with due regard to any late running and to the priority to be accorded to certain movements.

On certain Railways, notably the Victorian Railways in Australia, a *partial form of remote control,* has been installed, enabling the points and signals at one station to be operated from a neighbouring one, which allows for example of avoiding the difficulty of having to keep staff at an existing crossing place or at one which is to be established in an isolated inaccessible location.

Generally speaking, however, the remote control of stations is provided in a much more complete form, covering their entire number throughout a line. This is the *centralised traffic control* for single lines introduced by the American Railways.

We have already pointed out that this equipment was justified by the system of working single lines obtaining there, based on the train crews being responsible for applying the rules which provide for safety. The question arises whether those railways which do not work in this manner and use rules resting on the station staff seeing that safety is ensured, can obtain worthwhile advantages from centralised traffic control either from the point of view of effecting economies in working costs or to achieve what we are specially concerned with in this article, improvement in capacity.

From the financial point of view, the capital needed for a C.T.C. installation is relatively large, since both remote control and detection (proving) of equipment at stations must be provided for, with electric operation of points and signals and automatic signals on the single line itself.

Generally speaking, it hardly seems possible to compensate for the heavy financial outlay and charges by reducing station staff, especially when it is considered that at many of them the staff engaged on the ordinary commercial business work can very often attend to signalling, provided of course that the equipment for working the points and signals is such as to simplify what they have to do.

More than this, the possibility of abolishing station staff requires to be considered in connection with the form

of general traffic working organisation adopted on the railway concerned. In this respect, many managements are in a very different situation from that which obtains in America, for while making the station staff generally responsible for safety of working, they have placed certain duties relating to that on the train crews, such as protecting their trains if stopped between stations, watching over their safe running, and so on.

These managements may therefore in investigating the possibility of effecting economies be led to consider either doing away with the station staff, or eliminating certain members of the train crews. On long lines with a large number of stations carrying only light traffic, working with train crews only, without any signalling duties having to be performed by station staff, would appear to be the more economical, but this is not the case where a line is carrying moderate or heavy traffic, bearing in mind the possibilities offered by modern operating methods of closing certain stations as signalling points and making the number of them open and carrying out signalling operations at any moment proportional to the traffic to be handled.

On lines of this character, provided with satisfactory signalling and block equipment, where the state of maintenance of rolling stock gives rise to few incidents and where the trains have continuous brakes, there is no difficulty in practice in running through trains with engine crews only.

This is the course now being followed by many railway systems, Belgium, France, Norway, Sweden... *and may be regarded as the natural consequence of the adoption of modern signalling and braking,* and the progress effected in that direction since the opening of the century.

This procedure is obviously more profitable for the railways concerned than would be the abolition of station staff and investing large sums in installing C.T.C.

As regards capacity, C.T.C. offers all the flexibility and convenience of working that can be desired, and automatic signalling which its use implies, is particularly valuable in allowing trains to follow at short intervals.

In addition, the traffic controller — now at the C.T.C. machine — is in a position to exercise his functions with the maximum exactitude and rapidity :

— firstly because the track circuit occupation indications grouped on the machine give him a constant bird's eye view of the exact position of every train;

— and secondly the direct control over stations allows of avoiding certain time losses which otherwise would arise in carrying out his orders by the stationmasters.

Nevertheless, the advantages with an equivalent track layout, are not so great as to permit of raising the maximum traffic capacity level much above that possible with signalling of ordinary well-known designs.

On the other hand, if contrary to the conditions serving as the basis for the arguments advanced in this article, it should be a question of obtaining the maximum capacity by altering both track layout and signalling, we believe that

the application of C.T.C. would be of particular interest for it would allow of new crossing places being constructed, or the loop lines at many others being extended to cover several kilometres, and even of having alternate sections of double and single line without any difficulty being experienced either in the working or in providing satisfactory rules to cover it.

From this point of view C.T.C. lends itself to any arrangement of tracks and thus can contribute in exceptional cases where its use is particularly justified to raise the limit of capacity of single lines.

Conclusion.

Some readers may have thought that we have dwelt at too great length on ideas concerning the regulations and equipment to be used in single line signalling and look upon such, as far as they are concerned, as elementary. Experience goes to prove, however, and the discussions at the Rome Congress confirmed, how difficult it is to make oneself clear if the principles under discussion are not accurately defined. It is to avoid therefore any misunderstanding that we have tried to make our analysis of the means likely to increase flexibility and rapidity of single line working as exact and plain as possible.

Apart from arranging for suitable operating rules properly so called, which may be so worded as to eliminate any source of hindrance to efficient working, the means above referred to can be summarised as follows :

1. Installation of traffic control (dispatching);

2. Provision of maximum facilities for flexible operation of points and signals at stations, that is to say :

a) introduction of trailable point mechanisms, to eliminate any actual operation of the points during normal crossing movements;

b) provision for receiving two stopping crossing trains simultaneously;

c) operation of the facing points from a distance and not locally on site, to facilitate carrying out crossings where the second train runs through without a stop;

3. Installation of single line block apparatus, on one of the various possible systems, needing to be compared on the basis of cost and the savings to be obtained with them :

i.e. manual block with treadle and track circuit control,

or an automatic signalling;

4. In exceptional cases, installation of C.T.C. for lines which, despite the application of the measures above mentioned would remain overloaded (or for lines running through sparsely populated areas).

It will be seen that a fairly extensive range of methods is available for increasing the capacity and efficiency of single lines, from which railway officers can select, having regard to the characteristics of the line and the cost involved, the arrangement they find best suited to their requirements. Any one of these methods taken by itself could have only a limited effect on the position, but the working of single lines is a real « race against time » where the gain of even

a very short interval is not to be disdained.

Is it possible to give a guide to the making of such a choice by estimating the cost of the arrangements we have suggested as being of value, as well as the advantages to be obtained from them ?

Unfortunately we are unable to do that, firsly because the cost of equipment varies too greatly between one country and another; charges of various kinds, protective duties levied by countries which have to import signalling apparatus, etc., all affect the economic position to a marked extent. In the second place any increases in capacity likely to be obtained would themselves be as vague and undetermined, as is the idea of capacity properly so called, when applied to a single line. This very idea depends indeed on too many factors all tied to the characteristics of the traffic. All things being equal it is easier to obtain a high capacity on short lines than on long ones with numerous crossing places. In addition, a constantly regular type of service, with no great variations in either passenger or goods traffic, and the reliability of the traction system, are the most favourable elements in obtaining the highest efficiency.

Such efficiency itself, however, is to a great extent theoretical, depending as it does on the requirements of the Traffic Department relative to the regularity and quality of the passenger service, from the point of view of speed, frequency, etc.

We can therefore only continue to treat the subject from a qualitative standpoint, pointing out that traffic control arrangements, trailable point equipment at stations and manual block apparatus with treadle control are relatively inexpensive and in practice allow of obtaining very satisfactory effective results.

On the other hand, operating points from a distance and automatic signalling are costlier and not to be recommended as a general practice. They call for careful financial investigation, preceded by preliminary practical trials, when circumstances require.

To make this quite clear, it appears to us of interest to give particulars of the capacity actually attained on certain European lines (not always provided, however, with the whole of the equipment we have enumerated) regretting being unable for want of the information to provide similar details for other countries.

In Germany, the *Gemunden-Waigolhshausen line,* 46 km (28.5 miles) with 7 intermediate stations, situated 3 to 7 km (1.8 to 4.3 miles) apart, has traffic control and single line block and handles 70 trains daily.

In Italy, the *Battipaglia to Reggio-Calabria line,* by reason of its length and density of traffic forms one of the most heavily loaded single lines in Europe. It is operated under traffic control, manual block and colour-light signals. It is 400 km (248 miles) long, has 78 stations at a maximum distance apart of 8.5 km (5.3 miles). Traffic varies considerably and when the spring vegetable traffic is being dealt with, can reach 65 trains daily.

As regards France, where the most heavily worked single lines are equipped with traffic control and single line block with treadles, we may mention the following :

Toulouse-Tessonnières, 58 km (36 miles) with 8 stations, 4 to 9 km (2.4 to 5.5 miles) apart, and 54 trains daily;

Aix-les-Bains - Annecy, 40 km (24.8 miles) with 6 stations, 4 to 8 km (2.4 to 4.9 miles) apart and 50 trains per 20 hours day, the line being closed at night for reasons of economy. The maximum capacity for 24 hour working would be about 70 trains daily.

In Switzerland, the most important single lines mentioned below have no traffic control but are equipped with manual block, having in some cases intermediate block posts. These are :

Rupperswil-Goldau, 57 km (35.4 miles) with stations at from 2.5 to 8.5 km (1.5 to 5.3 miles) and 62 trains daily; and

Solothurn-Oensingen, 15 km (9 miles) with 4 stations at 2 to 5.7 km (1.2 to 3.5 miles) and 100 trains daily.

These various examples show that it is possible using operating methods based on the station master attending to the signalling and with relatively simple signalling equipment, to get quite appreciable capacity, reaching to something like 70 trains daily.

Certainly in these cases the lines are very well equipped from the point of view of the number of crossing places and such a result evidently could not be attained where the stations are further apart. It is to be observed, however, that the upper limits of capacity that the traffic department could be expected to hope for are approached very closely and that, short of re-arranging the track layout, the installation of C.T.C. would not effect any appreciable improvement in the position. This explains why the European Railways have not, up to now, turned to such working. The only installation of which we are aware is at present under construction in Spain on the line from Ponferrada to Torre.

[625 .144 .1]

Trackwork with long rails,

by Nils LUNDÉN,

(Järnvägs Teknick Statsbahneingenjören, No. 1, 1954.)

A highly desirable property of any railway track is that it should enable the trains to pass smoothly and noiselessly. The demands on the track increase with high running speeds and greater density of traffic. Under load the track behaves elastically. In addition to its being well laid, we require that, ideally, the track should be absolutely uniform throughout its length. Practical considerations, however, rule out the possibility of such an ideal track; nevertheless, all such discontinuities, and variations as rail joints, change of ballasting material, uneven spacing of the sleepers, guard rails, etc, should be minimised. The most glaring discontinuity of a track occurs at the rail joint, which also is responsible for a considerable amount of the total track maintenance. In first-class trackwork, therefore, such joints should, as far as possible, be eliminated, that is to say, the rails should be welded to form a continuous track.

For many years, railway technicians were of the opinion that a track without joints could not be constrúcted. With the older methods of construction using flat-bottomed rails spiked directly to the sleepers, this was undoubtedly true, due to the weak fixing obtainable. On the tramways, where the lines were laid in the streets, and the inconvenience due to rail joints was particularly noticeable, it was soon found that the rails could be continuously welded, thus eliminating the inconvenience. With the track securely held, both laterally and vertically, within the road surface, the rails were found capable of absorbing, as constrained elastic deformations, the stresses induced by temperature variations.

For present-day traffic, with fast, heavy trains, a stable track devoid of lateral deflection, is required. These demands have given rise to our present trackwork with its crushed-stone ballast giving a secure bedding for the sleepers, and a fixing which keeps the rail and sleeper rigidly together. With such track it was soon discovered that the closely spaced joints previously used, were no longer required, and that the rails could be welded together into very much longer units. With this discovery, the welded track soon became the order of the day. A first requirement of a welded track is that it should not buckle under the compressive stresses induced in the rails when their temperature rises above that at which the track was laid. Several investigators have endeavoured to calculate the stresses necessary to induce buckling, and have also carried out tests on buckling in actual track sections.

The trackwork for the Underground System of Stockholm Tramways constructed with 43.2 kg rails and spring spikes, is thus calculated and tested to withstand a minimum compressive force of 110 tons; whilst several foreign tracks have been proved capable of withstanding up to 240 tons. It is on record that under the influence of sunrays, rails can on a hot summer-day, reach a temperature as high as + 60° C; whilst their temperature in winter may fall as low as — 40° C. The winter temperature in Stockholm has not fallen below — 30° C in recent years, whilst the rail-temperature in summer is not considered to rise above + 50° C. Observations on summer days during 1950 and 1951 on the Ängby and Hökarängs lines, have resulted in measurements of not more that + 45° C.

What, then, are the forces induced in the track as a result of such temperature variations, if movement of the rails is prevented?

A rail of length L, having a coefficient of expansion α, will, for a temperature range t, change its length by an amount.

$$l = t \cdot \alpha \cdot L. \qquad \text{(eqn. 1)}$$

The same change in length l can be brought about by applying a force P to each end of the rail.

By the well-known law of mechanics, the change of length of a bar under the influence of a force P, can be written

$$l = \frac{P \cdot L}{F \cdot E} \qquad \text{(eqn. 2)}$$

where F = cross — sectional area
E = modulus of elasticity.

Eqn 1 and 2 give :

$$\frac{P \cdot L}{F \cdot E} = t \cdot \alpha \cdot L; \quad \frac{P}{F} = t \cdot \alpha \cdot E.$$

$\frac{P}{F}$ = stress in the fixed rail for a temperature change of one degree.

For steel E = 2.2×10^6 kg/cm² and = 0.000011.

For a one degree temperature change, one has then :

$$\frac{P}{F} = 1 \times 2.2 \times 1.1\ 10^{-5} = 24 \text{ kg/cm}^2.$$

Compressive Force.

In summer we may assume a highest temperature of + 50° C.

If the rail is welded at + 15° C, which is normal, then, for a temperature increase of 35° C, the rail experiences a stress of $35 \times 24 = 840$ kg/cm²

With a 43.2 kg rail having a cross-section of 55 cm², the force will be 55×840 = 46 tons; or, for two rails, about 90 tons. As shown above, the track should be able to take such a compressive force without buckling occurring.

Tension.

We assumed above a lowest winter temperature of — 30° C; that is, from the summer average of + 15° C, a temperature fall of 45° C, which gives rise to a force in the rails of :

$$24 \times 45 \times 55 = 60\,000 \text{ kg} = 60 \text{ tons.}$$

It ought, by what follows, to be possible to overcome this large force also. For practical reasons we do not consider temperatures that occur only once in ten years. Assuming instead a lowest winter temperature of — 20° C, this gives a force in the rails of $35 \times 24 \times 55 = 46$ tons.

The force in the rail is transmitted through the rail spike, rubber pad, and bearing plate to the sleepers and ballast. We estimate that our spring-steel spikes hold with a force of about 500 kg. Bearing in mind the possibility in practice of obtaining but an imperfect hold, and also fatigue of the spike, one ought with safety to be able to reckon on 400 kg per spike as a practical working value. The force in the spike is transmitted by friction between the rail and the rubber pad to the bearing plate and sleeper.

The friction coefficient between iron and rubber has not been agreed upon universally. American investigators have been able to determine that for dry surfaces the value reaches, and even exceeds, unity. When water is present and, under certain circumstances, acts as a lubricant, the friction can drop to a value as low as 0.02. That the value can reach, and even exceed, unity, is probably explained by the fact that the rubber, if I may term it so, « korrosionsvulkaniseras » to the steel. This might well be the case when using rubber pads between rail and bearing plate, with a good fastening. In the course of replacing old rails the rubber pads have come away with the rails, and have literally had to be torn from them. Thus we are not called upon to consider a friction coefficient of less than unity, and the maximum shearing force from 4 spikes would be 4×400 = 1 600 kg. The allowable shearing stress for rubber varies with quality and use. For technical grades it may be taken as from 5 to 15 kg/cm². In the case in question it was considered permissible to take the

allowable shearing stress as 10 kg/cm^2 The shearing area of the pads is 13.3 $\times$ 17.5 $\times$ 10 = 2.5 tons. The rubber pads, therefore, are adequately capable of taking the above induced shearing forces.

Next, how long a rail is required to take the above-mentioned tension of 46 tons? Every spike is capable of transmitting 400 kg through the pad and bearing plate to the sleeper; or, for a three-spike fixing, a total of 1 200 kg, and, for a four-spike fixing, 1 600 kg. With a sleeper spacing of 87 cm we get a force per metre of track of:

$$3 \text{ spikes}, \frac{1\,200}{0.87} = 1.4 \text{ ton/m}$$

$$4 \text{ spikes}, \frac{1\,600}{0.87} = 1.8 \text{ ton/m}$$

or for the force of 46 tons with

$$3 \text{ spikes } \frac{46}{1.4} = 35 \text{ metres of track}$$

$$4 \text{ spikes } \frac{46}{1.8} = 25 \text{ metres of track.}$$

In a track longer than 70 or 50 m we thus have at least 35 or 25 m, respectively, between the joints bounding the forces which can, under any conceivable circumstances, arise due to variations of temperature; and so, with a long, continuously welded track we have no other problems than those we already have experienced with, our 90 and 120 metre railway tracks, which have been in use these past ten years. The difficulties arise at the joints.

How large a movement must we anticipate at a joint in a welded track with 4-spike fixing? With the above-mentioned lowest winter temperature, the tension in the rails can amount to 46 tons. For 25 m from the joint this force is transferred to the road bed by means of part forces at every sleeper. The contraction of the track, that is to say, the gap between rails can be determined in the following manner :

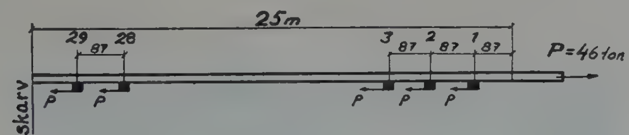


Fig. 1.

The force P opposes the sleeper-forces p. The sleeper spacing is 87 cm. At sleeper 1 the force P is diminished by p; at sleeper 2 by $2p$, and so on. By equation 2 the change of length is:

$$l = \frac{P \cdot L}{F \cdot E},$$

and thus for the first sleeper-interval :

$$\frac{87\ (P - p)}{F \cdot E};$$

for the second sleeper-interval :

$$\frac{87\ (P - 2p)}{F \cdot E};$$

and so on.

For 25 m of track we have :

$$\frac{25}{0.87} = 29 \text{ terms},$$

so that Σ changes in length :

$$= \frac{87\ (P - p + P - 2p + P - 3p .... P - 29p)}{F \cdot E}$$

$$= \frac{87}{F \cdot E}\ [29P - p\ (1 + 2 + 3 + ... 29)]$$

$$= \frac{87}{F \cdot E}\ (29P - 29p \times 15)$$

After substituting for P = 46 000 kg and p = 1 800 kg, as also for F and E, we have that the total change in length = 0.39 cm = about 4 mm.

Fig. 2.

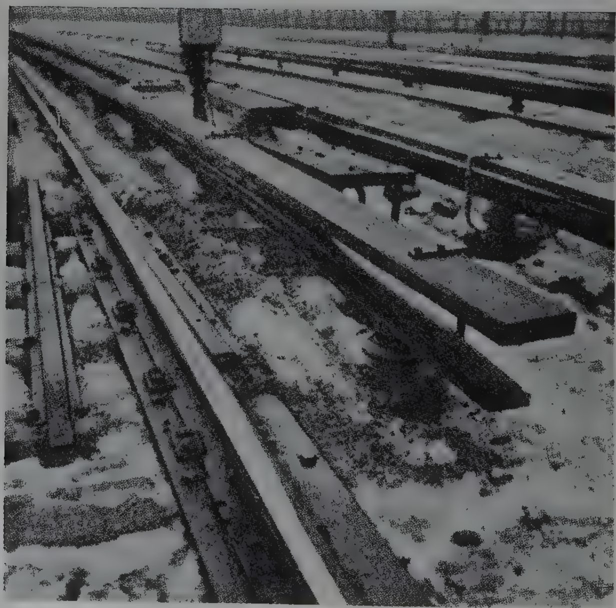


Fig. 3.

Under the given conditions a rail-gap of 8 mm is thus adequate. We have not as yet reckoned with any tension taken by the fish-joint. In order to withstand the tension induced in the rail by this contraction of 4 mm, the fish-plate should, by eqn 2, be capable of taking a force, as shown below :

$$l = 0.4 = \frac{P.\ 2\ 500}{F \cdot E}\ ;$$

$$P = \text{about } 20\ 000 \text{ kg} = 20 \text{ tons.}$$

Tests carried out at a research laboratory have shown that, besides ordinary joints, those, insulated with fibre packing, can take with 4-hole fish-joints, about 20 tons; and with 6-hole fish-joints, about 30 tons.

Under the given conditions, therefore, there should result no opening of the joints.

Up till now we have, however, assumed that the forces from the sleepers are transferred through the ballast to the road bed, thus binding the track. This, however, is not the case.

Under the dynamic influence of the train, the track behaves elastically, and loosens the sleepers in the ballast, after which, if the rail fastening is good, they take the ballast with them; that is to say, the track moves as a whole. Such movement depends on a variety of factors such as braking- and accelerating stretches, the nature of curves, gradients, temperature differences between the two rails, etc, and is virtually impossible to determine. Observations of such rail movement have shown that the same track can move in opposite directions, at one time the whole track moving up a gradient, and again, under different circumstances, in the downward direction. Thus, to obtain a track with closed joints, one can therefore recommend the following alternatives :

a) trackwork with a firm anchorage for the sleepers, by way of example, experimental track in a tunnel (fig. 2);

b) fish-joints of such a length (8 to 10 holes) that they are able to take the resultant tension (several hundred recently installed 8-hole joints have proved satisfactory up till now); or

c) in the neighbourhood of an insulation joint, the insertion of dilatation joints (joints de dilatation) so that the insulation joint may be drawn as tight as possible, and movement in the end of the rail must be taken by such inserted lengths (fig.3).

NEW BOOKS AND PUBLICATIONS.

[385 .02]

Directory of Railway Officials & Year Book, 1954-1955. — London : Tothill Press Limited, 33 Tothill street, Westminster, S. W. 1. — One volume of 530 pages (8 1/2 × 5 1/2 in.) Price : 40 sh. net.

The *Directory of Railway Officials & Year Book 1954-1955* reaches with the present volume its 60th year of publication.

The first edition was compiled from official sources and issued in 1895, and at that time some 270 pages sufficed to cover the text including an index to countries, an index to names of railways and the comprehensive personal index of railway officials, which is still a noteworthy feature of the volume.

The present edition should prove as valuable as its predecessors. and there has been no markedly change in the presentation of this volume with the current edition, but the revision of individual entries has been this time more extensive. All entries continue to be divided into one of two main divisions, namely, British Commonwealth (regardless of Dominion or Colonial status) and Foreign; each of these sections is again subdivided geographically into continents and countries.

In the Asian section, particulars for the Republic of Korea have been added. There are one or two additional entries, including those for the new Quebec North Shore and Labrador Railway in Canada, and the new underground systems in Toronto and Stockholm.

Once again, it has been impossible to secure reliable information from most of the « iron curtain » countries of Eastern Europe, Russia and China.

Statistics specially prepared by the British Transport Commission are included.

As in the past, this manual will be found of invaluable interest to all those interested in railway matters.

A. U.

MONTHLY BIBLIOGRAPHY OF RAILWAYS (1)

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(NOVEMBER 1954)

[016. 385. (02]

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CUNLIFFE (J.P.). — **Train auto alarm system in Malaya.** (900 words & figs.)

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Pensylvania Railroad clearance car. (600 words & figs.)

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JOHNSON (Patrick). — **Gas turbines.** (1 200 wor & figs.)

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IARRIS (A.R.). — **C & NW replaces old truss ns.** (1 700 words & figs.)

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IURSCH (S.R.). — **Greater M/W efficiency... how as been accomplished.** (1 900 words, figs & table.)

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RESSI (G.). — **Locomotive tipo Ma 2-10-2** per le ovie Greche della S.E.K. (2 000 parole & fig.)

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MUSSO (G.). — Natura fisica della **difesa dalla corrosione per elettrolisi.** (4 000 parole & fig.)

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POLESE (A.). — Sul **calcolo del sistema binario-traverse** con particolare riguardo ai fenomeni di **instabilità**. (3 000 parole & fig.)

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SAVOJA (A.). — Il problema del **rinnovamento del materiale rotabile.** (3 000 parole.)

1954 621 .336
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CIPRIANI (A.). — Le **azioni del pantografo sulla linea di contatto.** (4 500 parole & fig.)

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La **frenatura electrica a recupero nelle ferrovie metropolitane e suburbane.** (1 500 parole & fig.)

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Dr.-Ing. V. PERRONE. — **La Ferrovia Metropolitana a Roma.** X-13 : Materiale rotabile. (8 000 parole, tabelle & fig.)

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La prima importante **elettrificazione ferroviaria in Australia con corrente continua a 1 500 V.** (2 500 parole & fig.)

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PONT (W.A.C.). — **De oploophelling bij rangeerheuvels.** (1 000 woorden & fig.)
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VAN DEN BRINK (M.). — **Trein- en rangeerdienst.** (1 800 woorden & fig.)
BOOT (B.C.M.). — **Rangeermethoden.** (2 000 woorden & fig.)
VAN LOON (O.C.A.). — Concentratie van **rangeeremplacementen.** (2 500 woorden.)
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ROOZEVELD VAN DER VEEN (A.F.). — **Invloed van de dwarsafstand van de draagveren op de rustige ligging van de bak** van een spoorwegvoertuig voor normaalspoor. (1 500 woorden, tabellen & fig.)

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HONDIUS (H.) & VAN OMME (N.). — Ontwikkeling van **dieselhydraulische transmissiesystemen.** (5 000 woorden & fig.)

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DE JONG (K.F.). — Een **nieuwe electrische rangeerlocomotief** voor de Zweedse Spoorwegen. (500 woorden & fig.)

1954 **656** .212 .

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PENTINGA (K.J.). — **Gelijktijdig heuvelen va wagens.** (2 500 woorden & fig.)

In Serbo-Croat (= 91.882).

Tehnika. (Belgrade.)

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